US Army Corps of Engineers
Construction Engineering
Research Laboratories

USACERL Special Report 96/65
May 1996

Military Land Management Research Tools: An Annotated Bibliography

by
Harold E. Balbach

Management of U.S. Army training lands is accomplished by two types of personnel, the active land manager, who is most focused on methods for identification and remediation of the environmental consequences of supporting the military training and testing mission, and the researcher, who develops management tools and techniques to better assist the land manager. This bibliography is arranged so papers and reports believed most relevant to the active land manager are in one section of each topic area, and those of more interest and value to the researcher are in a separate section.

The bibiliography covers these 14 topic areas: (1) Impacts of Military Training, (2) Measurement and Characterization of Vegetation, (3) Measurement and Characterization of Wildlife, (4) Characterization of Soils, Erosion, and Erosion Protection, (5) Land Management Principles, (6) The Land Condition-Trend Analysis Process, (7) Training Related Noise Management, (8) Characterization and Management of Threatened, Endangered, and Sensitive Species, (9) Survey and Management of Cultural Resources, (10) Assessment of Environmental Impact for NEPA Compliance, (11) Environmental Modeling in Land Management Applications and Related Geographic Information System Technology, (12) Environmental Education and Awareness, (13) Land Contamination as Related to Training and Testing Activities, and (14) Management of Fugitive Dust.

19960606 037

DTIC QUALITY INSPECTED 1

Approved for public release; distribution is unlimited.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY *(Leave Blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	May 1996	Final

4. TITLE AND SUBTITLE
Military Land Management Research Tools: An Annotated Bibliography

5. FUNDING NUMBERS
4A162720
A896
T95, TP5, TJ6

6. AUTHOR(S)
Harold E. Balbach

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Construction Engineering Research Laboratories (USACERL)
P.O. Box 9005
Champaign, IL 61826-9005

8. PERFORMING ORGANIZATION REPORT NUMBER
SR 96/65

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Deputy Chief of Staff for Operations and Plans
ATTN: ODCSOPS
400 Army Pentagon
Washington, DC 20310-0400

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
Copies are available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)
Management of U.S. Army training lands is accomplished by two types of personnel, the active land manager, who is most focused on methods for identification and remediation of the environmental consequences of supporting the military training and testing mission, and the researcher, who develops management tools and techniques to better assist the land manager. This bibliography is arranged so papers and reports believed most relevant to the active land manager are in one section of each topic area, and those of more interest and value to the researcher are in a separate section.

The bibiliography covers these 14 topic areas: (1) Impacts of Military Training, (2) Measurement and Characterization of Vegetation, (3) Measurement and Characterization of Wildlife, (4) Characterization of Soils, Erosion, and Erosion Protection, (5) Land Management Principles, (6) The Land Condition-Trend Analysis Process, (7) Training Related Noise Management, (8) Characterization and Management of Threatened, Endangered, and Sensitive Species, (9) Survey and Management of Cultural Resources, (10) Assessment of Environmental Impact for NEPA Compliance, (11) Environmental Modeling in Land Management Applications and Related Geographic Information System Technology, (12) Environmental Education and Awareness, (13) Land Contamination as Related to Training and Testing Activities, and (14) Management of Fugitive Dust.

14. SUBJECT TERMS
bibliography
land management
military installations
training lands

15. NUMBER OF PAGES
146

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	SAR

Foreword

This report was prepared for the U.S. Army Deputy Chief of Staff for Operations and Plans (ODCSOPS) with funding from Project 4A162720A896, "Environmental Quality Technology"; and support through Work Units EN-T95, "Decision Support Technologies for Training Area Management;" EN-TP5, "ITAM Process Integration;" and LL-TJ6, "Training Land Requirements Analysis."

The assembly of the bibliography was performed by the Planning and Mission Impact Division (LL-P) of the Land Management Laboratory (LL), U.S. Army Construction Engineering Research Laboratories (USACERL). Dr. Harold E. Balbach was the principal investigator. Robert M. Lacey is Acting Chief, CECER-LL-P; Dr. William D. Severinghaus is Operations Chief, CECER-LL; and William D. Goran is Chief, CECER-LL. The USACERL technical editors were Gloria J. Wienke and Linda L. Wheatley, Technical Resources Center.

Thanks go first to the more than 40 principal investigators in the Land Management Laboratory who provided input to this document. Special acknowledgements are made to the following persons for their assistance in the preparation of introductions to certain sections of the bibliography: William Whitworth, Robert R. Riggins, and Drs. Larry Pater, John Isaacson, David Tazik, and Michael Denight. Special thanks go to Dr. James Westervelt, whose independent research into environmental modeling provided the majority of entries and summaries within that topic area. Thanks also are acknowledged for the assistance of former USACERL researchers Drs. Robert Brozka, Calvin Bagley, and Richard Raspet, and David Kowalski and John Fittipaldi, who provided many entries based on their research at USACERL and elsewhere.

COL James T. Scott is Commander and Acting Director, and Dr. Michael J. O'Connor is Technical Director of USACERL.

Contents

SF 298 1

Foreword 2

Introduction 5

Area 1: Training Impacts 8
1A: Applicable Results 9
1B: Underlying Research Information 13

Area 2: Measurement and Characterization of Vegetation 20
2A: Applicable Results 20
2B: Underlying Research Information 23

Area 3: Measurement and Characterization of Wildlife 26
3A: Applicable Results 27
3B: Underlying Research Information 31

Area 4: Characterization of Soils, Erosion, and Erosion Protection 34
4A: Applicable Results 36
4B: Underlying Research Information 38

Area 5: General Land Management Issues 41
5A: Applicable Results 41
5B: Underlying Research Information 50

Area 6: The Land Condition-Trend Analysis (LCTA) Process 59
6A: Applicable Results 60
6B: Underlying Research Information 62

Area 7: Environmental Noise (Training-Related) 64
7A: Applicable Results 67
7B: Underlying Research Information 71

Area 8: Threatened, Endangered, and Sensitive Species Issues 76
8A: Applicable Results 77
8B: Underlying Research Information 80

Area 9: Cultural Resources 82
9A: Applicable Results 84
9B: Underlying Research Information 88

Area 10: Environmental Impact Assessment 89
10A: Applicable Results 90
10B: Underlying Research Information 92

Area 11: Environmental Modeling in Land Management Applications and Related Geographic Information System (GIS) Technology 95
11A: Applicable Results 96
11B: Underlying Research Information 97

Area 12: Environmental Education and Awareness 128
12A: Applicable Results 130
12B: Underlying Research Information 131
12C: Products Developed and Distributed 131

Area 13: Land Contamination 136
13A: Applicable Results 136
13B: Underlying Research Information 138

Area 14: Management of Fugitive Dust 141
14A: Applicable Results 142
14B: Underlying Research Information 144

Distribution

Introduction

The following bibliography is prepared to assist persons with interests in the management of military training lands. Broadly speaking, there are two types of interests recognized: first, that of the land manager, who may be assumed to be most focused on methods and techniques for identification and remediation of the environmental consequences of supporting the military training and testing mission. Second, that of the consultant or researcher who is charged with developing management tools and techniques to better assist the land manager.

Recognition of these two needs has resulted in the inclusion of material that varies greatly in its level of presentation, focus, and relevance. To assist the reader, a two-way division of the material has been performed. The first division is that of aggregation of these references and summaries into 14 topic areas that focus on such different subjects as training noise and soil loss calculations. The second division, within each of these topics, is between those reports and papers believed most relevant to the active land manager versus those of more interest and value to the researcher. These sections are referred to within the bibliography as part "A" for *Applicable Results*, i.e., those containing material of direct applicability to land management, and part "B" for the *Underlying Research Information*, which is intended largely for use in research and development. Many publications in this latter category are highly technical and have resulted from basic research into the topic.

The 14 topics included are:

1. Impacts of Military Training
2. Measurement and Characterization of Vegetation
3. Measurement and Characterization of Wildlife
4. Characterization of Soils, Erosion, and Erosion Protection
5. Land Management Principles
6. The Land Condition-Trend Analysis Process
7. Training Related Noise Management
8. Characterization and Management of Threatened, Endangered and Sensitive Species
9. Survey and Management of Cultural Resources
10. Assessment of Environmental Impact for NEPA Compliance

11. Environmental Modeling in Land Management Applications and Related Geographic Information System (GIS) Technology
12. Environmental Education and Awareness
13. Land Contamination as Related to Training and Testing Activities
14. Management of Fugitive Dust.

Clearly, some overlap may be seen among these topic areas. Where this has been recognized, a citation has been included under more than one topic area. Some citations appear in as many as three or four categories where it was believed to be appropriate.

The annotations, or summaries, that accompany many of the citations included here were prepared to assist the reader to determine, more accurately than merely from reading a title, whether or not the report contains material of interest and applicability to a particular need. Almost all of the papers for which summaries are provided are Technical Reports published by the U.S. Army Construction Engineering Research Laboratories (USACERL), the institution where a majority of the research cited was performed. Acknowledging that original distribution of these reports may have been incomplete and that reports received may not have been retained, the reference number assigned to each by the Defense Technical Information Center (DTIC) has been included so copies may be obtained. This "ADA" reference number, together with the title, should be used by Department of Defense (DOD) personnel to request copies directly from the DTIC.

At this time, DOD personnel should transmit their requests for publications that include an ADA number to DTIC through their library to one of the following addresses:

DTIC Customer Service Help Desk
Special Programs Branch (DTIC-BLS)
Defense Technical Information Center
8725 John J. Kingman Road, Suite 0944
Fort Belvoir, VA 22060-6218

Telephone: Commercial (703) 767-8222/DSN 427-8222
Toll Free: 1-800-CAL-DTIC (225-3842), menu selection 7
FAX: Commercial (703) 767-8228/DSN 427-8228
E-mail: help@dtic.mil

The DTIC Uniform Resource Locator (URL) for internet assistance is:
http://www.dtic.mil:80/dtic/generalinfo.html

Nondefense agencies and persons should order copies of USACERL and other government reports from the National Technical Information Service (NTIS) using the full title, report number, and author's name(s), through the reader's appropriate ordering procedures. There is a charge for the publications, which will be stated at the time the order is processed. Orders may be placed through one of the following:

The NTIS Sales Desk is available between 8:30 a.m. and 5:00 p.m., Eastern time, Monday through Friday.

- Sales desk (703) 487-4650
- Subscriptions (703) 487-4630
- TDD (hearing impaired only) (703) 487-4639

Mail orders: Send to NTIS, 5285 Port Royal Road, Springfield, VA 22161.

Fax orders: (703) 321-8547

E-mail orders: orders@ntis.fedworld.gov

The NTIS URL for ordering information is http://www.fedworld.gov/ntis/howto.htm

USACERL has no additional copies of any of these reports available for distribution. In Area 11, where many important researchers appear not to formally publish their works as printed paper documents, the references given to these works are in terms of URL "addresses" of postings on WWW.

Area 1: Training Impacts

The impacts associated with military training are, at once, both subtle and obvious. When a tracked vehicle overrides a shrub, the plant is crushed and may be killed. But, the shrub may resprout from the base more vigorously than before, creating a better condition than before the event. The weight of a 60-ton vehicle must compact the soil where it passes...or must it? What *is* the ground pressure of a tank? In fact, it may be less (per square inch) than that of a loaded pickup truck. For how long does this compaction persist? A week? A month? A year? For decades? When USACERL began research in this area in 1971, a few facts directly relating to individual military vehicles were known, but the overall consequences of training for combat maneuvers could only be inferred through examination of old training areas.

Early studies by USACERL and USAWES (the U.S. Army Waterways Experiment Station) concentrated on simple identification of the nature and extent of the effects of training activities. How could...or should...we characterize field training activities? By the type of unit? By the number of personnel? By the number of miles driven in the field? By the number and types of vehicles assigned? What about after a field exercise? How many signs of tracks were found per acre? Was there vegetation regrowth in the track scars? How many and what types of songbirds were present? How many field mice were found per night of trapping? How did this compare to nearby areas that did not support Army training activity? Much of this effort approached being basic research; these were data that had simply never been acquired before. The ultimate question being answered, of course, was "What is the capacity of this area to support training?" This concept of "carrying capacity" is analogous to the same principle in range management, where it means the number of animals a range area will support for a certain period of time.

Although this introductory section is entitled "Training Impacts," examples of closely related citations may be found in most of the topic areas within this document. Noise, soils, wildlife, and many other topics have had a similar history. First, the absolute effects are identified, and later quantified. Then, differential effects may be found under varied field situations where season, moisture, time of day, wind direction, and other factors affect the severity of the resulting problem. Later, this information is used to develop management strategies that avoid adverse effects or minimize their consequences.

1A: Applicable Results

Ayers, P.D., and R.B. Shaw. Vegetation damage resulting from military vehicle traffic. Presented at the annual meeting of the ASA-CSSA-SSSA, Denver, CO, November 1991. *Agronomy Abstracts*, p 9.

Balbach, Harold E., and S. Coin, "Modeling Military Land Use Demands by Vehicle Categorization," *Agronomy Abstracts, 1984 Annual Meetings of the American Society of Agronomy*, December 1984.

Proposes that the numbers and types of vehicles authorized to a unit be multiplied by the typical mileage driven during an exercise, converted to equivalent "M-60" (tank) damage potential, and resultant "tank miles" be used to compare potential of different types of units to cause environmental damage to the training area.

Bern, C.M., and R.B. Shaw (eds). 1993. Maintenance and Repair of Military Training Lands. A National Symposium. Center for Ecological Management of Military Lands, Colorado State University, Fort Collins, CO. Technical Publication Series 93-1.

Conrad, C.C., R.E. Riggins, and C.M. Foley, *Land For Combat Training, Phase I Report*, Army Environmental Policy Institute, AEPI-IFP-1, December 1994, 60 pp.

An overview of the many pressures on the Army that are related to maintaining its base of training lands. Environmental regulations, including NEPA, the Endangered Species Act, the National Historic Preservation Act, among others, are each briefly discussed and the problems resulting from their application to Army lands are presented. The difficulty in calculating needs with any accuracy is also discussed, as are trends in environmental and military management processes.

Diersing, V.E., S.D. Warren, C.F. Bagley, and R.B. Shaw. *Management Options for Mitigating Natural Resource Training Impacts on Army Installations*. U.S. Army Construction Engineering Research Laboratory(ies) [USACERL] Technical Report N-90/12, June 1990. ADA224891.

A checklist of management actions that can streamline the decisionmaking process and increase the likelihood that managers will consider the full range of alternative actions.

Diersing, V.E., R.B. Shaw, S.D. Warren, and E.W. Novak. 1989. "A user's guide for estimating allowable use of tracked vehicles on nonwooded military training lands," *J. Soil Water Conserv.* 43(2):191-195.

Describes a method to avoid excessive soil erosion and ensure the continued availability of U.S. military training lands by establishing a basis for estimating allowable levels of sustained tracked vehicle use. The information gathered can be used to estimate maximum allowable use for each ecological response unit. Land managers can then verify that allowable use is not exceeded by measuring the percentage of the surface that appears tracked. Adjustments in allowable use are based on trends in the amount of ground cover and by observing changes in botanical composition. (Originally prepared as USACERL Report N-89/09).

Dubois, P.C., *Impacts on Soils and Vegetation at Yakima Training Center, Washington, from the Proposed Stationing of Mechanized or Armored Combat Forces.* Unpublished USACERL Report in Environmental Impact Statement, Stationing of Mechanized or Armored Combat Forces at Fort Lewis, Washington, September 1993.

Fittipaldi, J.J., and S.E. Hottman, "A Microcomputer System for the Prediction of Blast Noise Impacts," *Noise Control Engineering Journal XXVI*, No. 3, May-June 1989, 12 pp.

Goettel, R.G., H. Balbach, and W.D. Severinghaus, *Guidelines for Installations Natural Resource Protection During Training*, USACERL Technical Report N-104, October 1981. ADA107987.

Describes how U.S. Army installation personnel can assemble material for a training package that explains how to protect an installation's natural resources. Suggested text and artwork have been regionalized to allow a reasonable approximation of the specific environments found on most Army installations. Included are explanations of how the appropriate regionalized sections of the package can be selected and reproduced. Instructions are also provided on how an installation-specific map and information section can be prepared.

Goran, W.D., L.L. Radke, and W.D. Severinghaus, *An Overview of the Ecological Effects of Tracked Vehicles on Major US Army Installations*, 75 pp, USACERL Technical Report N-142, February 1983. ADA126694.

Various levels of field studies were done on 12 U.S. Army Training Doctrine Command (TRADOC) and U.S. Army Forces Command (FORSCOM) installations to provide a general overview of ecological disturbance caused by U.S. Army tactical vehicle training. Detailed quantitative and qualitative data were obtained from Forts Polk, Knox, Hood, and Lewis; supplementary semi-quantitative and qualitative studies were done at Forts Benning, Bliss, Carson, Drum, Irwin, Riley, and Stewart, and at Yakima Firing Range.

Hinchman, R.R., K.G. McMullen, R.P. Carter, and W.D. Severinghaus, 1990, *Rehabilitation of Military Training Area Damaged by Tracked Vehicles at Fort Carson, CO*, 60 pp. FEAP-TR-N-91/01. ADA232066.

Report of Facilities Engineering Applications Program (FEAP) project to develop and demonstrate ecologically effective and economically feasible soil rehabilitation and revegetation techniques to increase soil stability and provide a more realistic training environment at Fort Carson, CO.

Hinchman, R.R., W.D. Severinghaus, S.D. Zellmer, W.A. Mego, and D.O. Johnson, "Reveg/XD: A Computer Program for Revegetation Species Selection," 1990, *Agronomy Abstracts*, p. 9.

Johnson, D.O., R.E. Zimmerman, W.D. Severinghaus, R.M. Lacey, R.R. Hinchman, and R.P. Carter, 1990, *Return-On-Investment Study for Rehabilitation of Military Training Areas Damaged by Tracked Vehicles at Fort Carson, Colorado*, TR N-90/08, July 1990. ADA225951.

Presents a return on investment study of the benefits that would result from implementing a long-term vegetation management at Fort Carson and similarly at the Pinon Canyon Maneuver Site. Results presented show that land rehabilitation and maintenance are cost effective for the Army.

Krzysik, A.J., *Ecological Assessment of the Effects of Army Training Activities on a Desert Ecosystem: National Training Center, Fort Irwin, California*. USACERL Technical Report, N-85/13, Jun 1985. ADA159248.

Describes a study conducted at Fort Irwin, Cal., to assess the effects of large-scale Army Training maneuvers and war game scenarios on the installation's desert ecosystem. Additional objectives of the study were to develop rigorous methodologies for quantifying environmental impact assessments, to describe species/ habitat associations, and to quantitatively summarize the relative relationship of experimental and control sites on the basis of vertebrate community structure.

Krzysik, A.J., 1993. "Wetlands and riparian ecosystems," *The Military Engineer* 85:46-48.

Lacey, Robert M., and W.D. Severinghaus, *Natural Resource Considerations for Tactical Vehicle Training Areas*, USACERL Technical Report N-106, June 1981. ADA103276.

Provides land evaluation criteria and procedures for incorporating environmental and natural resource considerations into the process of choosing sites for tactical vehicle training. Elements addressed include land use, noise, terrain, soil, air quality, water quality, vegetation and wildlife. Procedures are suggested to lessen the impact of tactical vehicle training on these resources.

Riggins, Robert E., and J.C. Kaden, *Training Impact Prediction System Users Manual*, USACERL Interim Report N-85/12, May 1985. ADA158600.

Describes the use and implementation of the Training Impact Prediction System (TIPS) — an interactive, user-friendly, computer-based system Army planners and land managers can use to predict environmental impacts on Army Training lands. The system is accessed through the Environmental Technical Information System.

Schomer, Paul D., "A Model to Describe Community Response to Impulse Noise," *Noise Control Engineering Journal*, Vol. 18, No. 1, January/February 1982, pp 5-15.

Schomer, Paul D., "The Role of Helicopter Noise-Induced Vibration and Rattle in Human Response," *J. Acoust. Soc. Am.*, Vol. 81, No. 4, April 1987, pp 966-976.

Severinghaus, W.D., and M.C. Severinghaus, "Effects of Tracked Vehicle Activity on Bird Populations," *Environmental Management*, 6(2):163-169, 1982.

Shaw, R.B., and V.E. Diersing. 1990. "Tracked vehicle impacts on vegetation at the Pinon Canyon Maneuver Site, Colorado," *J. Environ. Qual.* 19(2):234-243.

Trumble, V.L., P.C. Dubois, R. Brozka, and R. Guette. "Military Camping Impacts on the Ozark Plateau, 1994," *Journal of Environmental Management*, 40:329 - 339.

1B: Underlying Research Information

Ayers, P.D., R.B. Shaw, V.E. Diersing, and J. Van Riper. 1990. Soil compaction from military vehicles. International Summer Meeting of the American Society of Agricultural Engineers. 22 p.

Balbach, Harold E., "Non-Point Source Soil Loss Regulations: Can Military Training Coexist?" *Agronomy Abstracts, 1987 Annual Meetings of the American Society of Agronomy*, November 1987. p.6

Krzysik, A.J., and Harold E. Balbach, "Quantifying and Monitoring Habitat Changes on Army Training Lands," *Agronomy Abstracts, 1989 Annual Meetings of the American Society of Agronomy*, October 1989. p.7

Diersing, V.E., E.W. Novak, and H.E. Balbach, "A Method for Calculating Allowable Use of Tracked Vehicles on US Army Maneuver Lands," *Agronomy Abstracts, 1985 Annual Meetings of the American Society of Agronomy*, December 1985.

Balbach, Harold E., V.E. Diersing, and E.W. Novak, "Resilience of Several Vegetative Communities to Compression from Tracked Vehicles," *Agronomy Abstracts, 1985 Annual Meetings of the American Society of Agronomy*, December 1985.

Dierenfeld, E.S. and E.W. Novak, *Quantification of hexachloroethane munitions and associated environmental chemical loads.* USACERL Technical Report N-87/17, Jun 1987. ADB114815L.

Documents the extent to which hexachloroethane (HC) smoke munitions are used on Army installations, calculates the environmental chemical loads resulting from this use, and assesses the munitions' potential hazardous effects to native flora and fauna. Three types of munitions were examined: smoke projectiles, smoke grenades, and smoke pots; their use by various Major Commands was quantified for FY81 through FY84.

Diersing, V.E., and W.D. Severinghaus, *The Effects of Tactical Vehicles Training on the Lands of Fort Carson—An Ecological Assessment*, USACERL Technical Report N-85/03, December 1984. ADA152142.

Describes field studies at Fort Carson, CO, to quantify the effects of Army tracked vehicle training on mammals, birds, vegetation, and soils. Both the pinyon-juniper woodland and shortgrass prairie were analyzed.

Diersing, V.E., and W.D. Severinghaus, *Wildlife as an Indicator of Site Quality and Site Trafficability During Army Training Maneuvers*, USACERL Technical Report N-86/03, December 1985. ADA163560.

Report on field studies on four prairies on Pinon Canyon Maneuver Site and Fort Carson, CO, during May-June 1983 to compare relationship of soils and vegetation, to bird and mammal species composition and abundance. Results suggest that the estimation of the numbers of each species on semiarid maneuver lands may be an effective management tool for installation land management.

Diersing, Victor E., B.R. Jones, S.D. Warren, D.W. Herbert, and E.W. Novak, *Juniper Chaining: A Vegetative and Soil Erosion Assessment of a Method of Rangeland Improvement on Ft. Hood, TX.* USACERL Technical Report N-87/05, Jan 1987. ADA178114.

Presents the results of an investigation conducted on Fort Hood, TX, during 1984-1985 to determine (1) the effect of mechanical chaining on the elimination of mature strands of Ashe juniper trees, (2) the natural re-establishment of herbaceous vegetation cover following chaining, and (3) the effects of chaining on soil erosion rates. Results show that chaining is effective in eliminating pure strands of juniper trees and is a viable option for increasing the amount of available training land while maintaining land resources.

Goran, W.D., and R.E. Riggins, "Geographic Information Systems for Training Land Evaluation," Army R,D&A (Research, Development and Acquisition), September/October 1983, pages 26-28.

Goran, W.D., H.E. Balbach and W.D. Severinghaus, 1982, Ecological Effects of Tactical Vehicles: An Overview, *Agronomy Abstracts, American Society of Agronomy, 1982 Annual Meetings*, Nov. 28-Dec. 3, Anaheim California. p 8.

Kerster, H.W., D.J. Schaeffer, and K.A. Reinbold, 1988, *Assessing Ecosystem Impacts from Simulant and Decontaminant Use*, CRDEC Technical Report CR-88059/ USACERL Technical Report N-88/15, July 1988. ADA196846.

Chemicals for simulation and decomposition of chemical warfare agents may alter the ecosystems of training sites and their environs. This report presents methods and proposes a newly devised approach to rank those chemicals for damage potential. Further data necessary to reduce ranking errors are identified, and chemical and ecological monitoring of training sites and their surroundings are recommended.

Lacey, R.M., and H. Balbach, *Evaluation of Areas for Off-Road Recreational Motorcycle Use Volume II: Alternate Soil Suitability Determination Methods*, USACERL Technical Report N-86, November 1980. ADA096528.

Volume II describes seven alternative methods for evaluating soil suitability for trailbike use, including simplified laboratory techniques.

Lacey, R.M., H. Balbach, S. Baran, and R.G. Graff, *Evaluation of Areas for Off-Road Recreational Motorcycle Use Volume I: Evaluation Method*, USACERL Technical Report N-86, November 1980. ADA096529.

Volume I describes how to evaluate soil suitability of areas for off-road recreational motorcycle (trailbike) use on land under the jurisdiction of the Department of the Army.

Lacey, R.M., R.S. Baran, H.E. Balbach, R.G. Goettel, and W.D. Severinghaus, "Off-Road Vehicle Site Selection," *J. Environ. Sys.*, 12(2):113-140, 1982.

Lacey, Robert M., D. McCormack, and D. Slusher, "Guide for Rating Soil Limitations for Off-Road Vehicle Trails", *National Soil Handbook, Part II*, (U.S. Department of Agriculture, Soil Conservation Service, April 1979), Section 403.6 (D).

Lacey, Robert M., H. Balbach, R.G. Goettel, and W.D. Severinghaus, *Planning for Off-Road Recreational Vehicle Use on Army Installations*, USACERL Technical Report N-132, July 1982. ADA119313.

Looks at the results of CERL's research conducted to help installation personnel comply with the policies, procedures, and criteria of Army Regulation 210-9, *Use of Off-Road Vehicles on Army Lands*. The report is for use primarily by recreational planners and land management personnel. It describes a general process and some specific considerations for planning for off-road recreational vehicle use on Army Lands.

Reinbold, K.A., R.S. Wentsel, E.E. Herricks, H.W. Kerster, and D.J. Schaeffer, "Environmental hazard ranking of chemical agent simulants." Proceedings of the *1986 U.S. Army Chemical Research, Development and Engineering Center Scientific Conference on Chemical Defense Research*, pp1057-1062, 1987.

Schaeffer, D.J., W.R. Lower, S. Kapilla, A.F. Yanders, and R.Wang, *Preliminary Study of Effects of Military Obscurant Smokes on Flora and Fauna During Field and Laboratory Exposures,* USACERL Technical Report N-86/22, Dec 1986. ADA176328.

Report of a study conducted to determine whether tests could be developed to demonstrate measurable changes in organisms exposed to smokes and to evaluate whether short exposure to smokes produced measurable changes in the organisms tested. Fog oil, hexachloroethane, and tank diesel smokes were tested in the field and chemically analyzed at distances from the source ranging from 15 to 150m. The tests developed were deemed adequate for indicating changes in the species caused by the smokes.

Schaeffer, D.S., H.W. Kerster, E.E. Herricks, K.A. Reinbold, E.W. Novak, and R.S. Wentsel, "Assessing ecosystem impacts from simulant and decontaminant use," *J. Hazardous Materials* 18:1-16, 1988.

Schomer, P.D, A.J. Averbuch, and L.N. Lendrum; *Army Blast Noise Warning and Monitoring System,* USACERL Technical Report N-88/03, Feb 1988. ADA191230.

The purpose of this study was to develop the noise warning and monitoring system (NWS) and to test its use, installation, operation and maintenance in typical Army environments. This system will alert the range control office when operational blast noise levels in a community exceed established levels, and will monitor the overall blast noise produced at an installation.

Schomer, Paul D., "A Survey of Community Attitudes Towards Noise Near a General Aviation Airport," *J. Acoust. Soc. Am.*, Vol. 74, No. 6, Dec 1983, pp 1773-1781.

Schomer, Paul D., "Decibel Annoyance Reduction of Low-Frequency blast Attenuating Windows," *J. Acoust. Soc. Am.*, Vol. 89, No. 4, April 1991, pp 1708-1731.

Schomer, Paul D., "Human Response to House Vibrations Caused by Sonic Booms or Air Blasts," *J. Acoust. Soc. Am.*, Vol. 64, No. 1, 1978, pp 328-330.

Schomer, Paul D., "Indoor Human Response to Blast Sounds Which Generate Rattles," *J. Acoust. Soc. Am.*, vol. 86, No. 2, August 1989, pp 665-673.

Schomer, Paul D., "Time of Day Noise Penalties," *J. Acoust. Soc. Am.*, Vol. 73, No. 2, Feb 1983, pp 546-555.

Schulz, K.A., and R.B. Shaw, and C.M. Bern. "Changes in tactical concealment cover with 5 years of military training at the Pinon Canyon Maneuver Site, CO." Presented at the annual meeting of the ASA-CSSA-SSSA, *Agronomy Abstracts*, Denver, CO, November 1991. p.12

Severinghaus, W.D., *Effects of Tracked Vehicle Activity on Higher Vertebrate Populations at Army Installations*, USACERL Technical Report N-177, April 1984. ADA142653.

Severinghaus, W.D., and W.D. Goran, *Effects of Tactical Vehicle Activity on the Mammals, Birds, and Vegetation at Fort Lewis, WA*, USACERL Technical Report N-116, November 1981, 45p. ADA111201.

Describes preliminary indications of ecological differences between select areas used for vehicle training and areas undisturbed by training, documents the procedures used to obtain this information, and analyzes Fort Lewis' ecosystem to verify the effects of training activities on ecosystems examined in previous research.

Severinghaus, W.D., W.D. Goran, G.D. Schnell, and F.L. Johnson, *Effects of Tactical Vehicle Activity on the Mammals, Birds, and Vegetation at Fort Hood, TX*, USACERL Technical Report N-113, September 1981. ADA109646.

Describes preliminary indications of ecological differences between select areas used for vehicle training and areas undisturbed by training, documents the procedures used to obtain this information, analyzes Fort Hood's ecosystem to verify the effects of training activities on ecosystems examined in previous research.

Severinghaus, W.D., R.E. Riggins, and W.D. Goran, *Effects of Tracked Vehicle Activity on Terrestrial Mammals, Birds, and Vegetation at Fort Knox, KY*, USACERL Special Report N-77, July 1979. ADA073782.

Intensive studies were done at Fort Knox, Kentucky, at three sites representative of a long-term training area, a short-term training area, and a control area. This report describes the survey procedures used and provides preliminary indications of ecological differences between Army tracked vehicle training areas and areas representing pre-training (no-training) conditions.

Shaw, R.B., and V.E. Diersing. 1989. "Evaluation of the effects of military training on vegetation in southeastern Colorado." Symposium Proceedings on Headwaters Hydrology, American Water Resources Association. p. 223-231.

Tazik, David J., *Effects of Army Training Activities on Bird Communities at the Pinon Canyon Maneuver Site, Colorado*, USACERL Technical Report N-91/31, Sep 1991. ADA248482.

Describes a study conducted at the Pinon Canyon Maneuver Site, CO, which investigated species habitat relationships of and impacts of Army training activities on avian communities in shortgrass prairie and pinyon-juniper woodlands. The study also identified wildlife indicators of habitat change using both species and guild approaches.

Tazik, David J., Dennis M. Herbert, John D. Cornelius, Timothy Hayden, and Billy Ray Jones, *Biological Assessment of the Impact of Military-Related Activities on Threatened and Endangered Species at Fort Hood, Texas*, USACERL Special Report EN-93/01, Dec 1992. ADA263489.

Looks at how the Army's military activities at Fort Hood, including maneuver, live fire, aviation training, and operational testing, may affect five Federally endangered species known to occur on Fort Hood. The black-capped vireo and the golden-cheeked warbler are of primary concern.

Tazik, David J., William D. Severinghaus, and Victor E. Diersing, *Annual Variation in Populations of Birds and Small Mammals on an Army Installation*, USACERL Interim Report N-86/02, Dec 1985. ADA164631.

Field studies report at Fort Carson, CO, to determine annual variations in bird and small mammal populations on shortgrass prairie and pinyon-juniper woodland study sites. Results showed some change, but concludes that the fluctuations in population are not related to training activities.

Thurow, T.L., S.D. Warren, and D.H. Carlson, *Tracked Vehicle Traffic Effects on the Hydrologic Characteristics of Central Texas Rangeland*, USACERL Technical Manuscript EN-95/02, Feb 1995. ADA293337.

A split-plot experiment to document the initial change and the temporal recovery pattern of hydrologic, soil, and vegetation characteristics following tracked vehicle passage (tracking). Treatments were characterized by different soil moisture conditions at the time of vehicle passage (wet or dry) and different tracking intensities (0,1,4 and 10 passes by a M2 Bradley Infantry Fighting Vehicle). The study was conducted at Fort Hood, located in the Cross-Timber Prairie ecological resource zone of Texas.

U.S. Army Technical Manual (TM) 5-631, Appendix G, *Off-Road Vehicle Site Selection*, January 1984.

Whitworth, W.R., *Abundance, Distribution, and Selected Characteristics of Nesting Raptors on the Fort Sill Military Reservation: 1987-92*, USACERL Technical Report 95/45, September 1995.

Area 2: Measurement and Characterization of Vegetation

Natural vegetation has been characterized by scientists for more than 100 years. Many standardized sampling procedures are known for every type of vegetation. Thus, the guidance shown here has been included because it is tailored to military installation needs or applications. Many specialized procedures, including those associated with the Land Condition-Trend Analysis (LCTA) effort, were developed by USACERL. Other techniques have been assembled into a set of manuals for easier field use by the Waterways Experiment Station. These techniques were designed for use in characterization of wildlife habitat, but procedures are universally applicable. The series of manuals (see Mitchell, pp 21, 22) is placed in Part 6.2, Vegetation Sampling, of the Corps of Engineers Wildlife Resources Management manuals. While these were generally prepared for use on the lands associated with water resources projects, the basic principles involved are easily transferred to the military installation context.

A more important aspect of the studies listed in this section has often been the measurement of the nature and degree of damage to vegetation as a result of various military training activities. The ability to prepare both qualitative and quantitative estimates of the anticipated effects of a particular exercise or type of training is vital to the development of a real understanding of the carrying capacity of those lands. Thus, the tools for measuring and characterizing vegetation, as with many of those for wildlife (see next chapter, Area 3), are important largely as they provide data for use in other management processes.

2A: Applicable Results

Doerr, T.B., and M.C. Landin, *Recommended Species for Vegetative Stabilization of Training Lands in Arid and Semi-arid Environments*, USACERL Technical Report N-85/15, Sep 1985. ADA161551.

Identifies key plant species that may be useful to installation land managers seeking to maintain or rehabilitate training lands in arid and semi-arid environments. The plant species are described in terms of their regional and

environmental adaptations, limitations, uses, establishment requirements, and availability. Recommendations for short and long term revegatation efforts are given for selected western installations.

Dubois, P.C., *Impacts on Soils and Vegetation at Yakima Training Center, Washington, from the Proposed Stationing of Mechanized or Armored Combat Forces.* Unpublished USACERL Report, 1993, in *Environmental Impact Statement, Stationing of Mechanized or Armored Combat Forces at Fort Lewis, Washington,* September 1993.

Hinchman, R.R., K.G. McMullen, R.P. Carter, and W.D. Severinghaus, *Rehabilitation of Military Training Area Damaged by Tracked Vehicles at Fort Carson, CO,* USACERL FEAP-TR-N-91/01, December 1990. 60 pp. ADA232066.

Report of Facilities Engineering Applications Program (FEAP) project to develop and demonstrate ecologically effective and economically feasible soil rehabilitation and revegatation techniques to increase soil stability and provide a more realistic training environment at Fort Carson, CO.

Hinchman, R.R., W.D. Severinghaus, S.D. Zellmer, W.A. Mego, and D.O. Johnson, "Reveg/XD: A Computer Program for Revegetation Species Selection," 1990, *Agronomy Abstracts*, p 9.

Mitchell, W, and H.G. Hughes, *Point Sampling. Section 6.2.1, U.S. Army Corps of Engineers Wildlife Resources Management Manual*, U.S. Army Waterways Experiment Station (CEWES) Technical Report EL-95-25, July 1995, 22pp + app. ADA299921.

Description of the use of the point frame and the step-point techniques to sample groundcover vegetation for frequency, density, groundcover proportions. Designed for use in characterization of wildlife habitat, but procedures are universally applicable. One of a series of manuals placed in Part 6.2, Vegetation Sampling, of the Corps of Engineers Wildlife Resources Management manuals.

Mitchell, W., and H.G. Hughes, *Line Intercept. Section 6.2.5, U.S. Army Corps of Engineers Wildlife Resources Management Manual*,CEWES Technical Report EL-95-22, July 1995, 17pp + app. ADA299915.

Description of the use of the line-intercept technique to sample shrubs and other rangeland vegetation for frequency, density, cover proportions. Examines cases where canopy is within intercept, but stems are not, a common problem area for many persons. Designed for use in characterization of wildlife habitat, but procedures are universally applicable. One of a series of manuals placed in Part 6.2, Vegetation Sampling, of the Corps of Engineers Wildlife Resources Management manuals.

Mitchell, W., and H.G. Hughes, *Visual Obstruction. Section 6.2.6, U.S. Army Corps of Engineers Wildlife Resources Management Manual*, CEWES Technical Report EL-95-23, July 1995, 16pp + app. ADA299564.

Description of the use of the visual obstruction technique to sample forest understory and oldfield communities for horizontal cover. This factor is a measure of vegetation, but results are applied largely toward estimates of habitat suitability for wildlife species known to be affected by the presence or absence of sight lines. One of a series of manuals placed in Part 6.2, Vegetation Sampling, of the Corps of Engineers Wildlife Resources Management manuals.

Mitchell, W., H.G. Hughes, and L.E. Marcy, *Prism Sampling. Section 6.2.3, U.S. Army Corps of Engineers Wildlife Resources Management Manual*,CEWES Technical Report EL-95-24, July 1995, 32pp + app. ADA299918.

Description of the use of the wedge prism to sample forested areas for tree density, basal area, and timber volume. Designed for use in characterization of wildlife habitat, but procedures are universally applicable. One of a series of manuals placed in Part 6.2, Vegetation Sampling, of the Corps of Engineers Wildlife Resources Management manuals.

Severinghaus, W.D., ed., *Proceedings: NATO CCMS Seminar Blue Book 159, Preservation of Flora and Fauna in Military Training Areas*, Conference Proceedings N-87/09, January 1987. ADA179754.

Proceedings of the NATO Committee on Challenges of Modern Society. Fifteen presentations were given on such topics as the effects of military training on soil, vegetation, birds, and mammals and the various programs being used by NATO countries to help preserve and conserve these resources.

Warren, S., G. Howard, and S. White, *Sources of plant materials for land rehabilitation*, USACERL Special Report EN-95/01, Dec 1994. ADA291934.

Land rehabilitation and maintenance must be preformed to minimize environmental degradation and improve the safety and realism of the training mission. One step in the rehabilitation and maintenance process is to purchase appropri-

ate plant materials, particularly locally endemic or adapted species. This report offers a list of plant material vendors in each state that may then be contacted by managers and trainers for solicitation of bids.

2B: Underlying Research Information

Diersing, Victor E., B.R. Jones, S.D. Warren, D.W. Herbert, E.W. Novak, *Juniper Chaining : a Vegetative and Soil Erosion Assessment of a Method of Rangeland Improvement on Ft. Hood, Texas.* USACERL Technical Report N-87/05, Jan 1987. ADA178114.

Presents the results of an investigation conducted on Ft. Hood, TX, during 1984-1985 to determine (1) the effect of mechanical chaining on the elimination of mature strands of Ashe juniper trees, (2) the natural re-establishment of herbaceous vegetation cover following chaining, and (3) the effects of chaining on soil erosion rates. Results show that chaining is effective in eliminating pure strands of juniper trees and is a viable option for increasing the amount of available training land while maintaining land resources.

Diersing, Victor E., David J. Tazik, and Edward W. Novak, *Growth Rate of Pinyon Pine (Pinus edulis) on Fort Carson and Pinon Canyon Maneuver Site, Colorado,* USACERL Technical Report N-87/20, June 1987. ADA183018.

Study of how long it takes for Pinyon Pine trees to grow to an adequate size to provide concealment for tracked vehicles. Age growth prediction equations were developed and the age structure of the current Pinyon Pine population was determined.

Douglas, P.P., and R.B. Shaw. "Rediscovery of Silene lanceolata on the Pohakuloa Training Area, Hawaii." Presented at the annual meeting of the ASA-CSSA-SSSA, Denver, CO, November 1991. p 9.

Dubois, P.C., G.M. Senseman, and C.F. Bagley. "Estimating Green Biomass on a Tall-grass Prairie using Landsat Thematic Mapper," presented at the 85th Annual Meeting, American Society of Agronomy, Minneapolis, Minnesota. November 1992.

Quinney, D.L., and R.B. Shaw. "Use of Land-Condition Trend monitoring and a GRASS GIS system in implementing a revegetation program in a National

Guard Training Area." Presented at the annual meeting of the ASA-CSSA-SSSA, Denver, CO, Nov. 1991.

Severinghaus, W.D., and W.D. Goran, *Effects of Tactical Vehicle Activity on the Mammals, Birds, and Vegetation at Fort Lewis, WA*, 45 pp, USACERL Technical Report N-116, November 1981. ADA111201.

Describes preliminary indications of ecological differences between select areas used for vehicle training and areas undisturbed by training, documents the procedures used to obtain this information, and analyzes Fort Lewis' ecosystem to verify the effects of training activities on ecosystems examined in previous research.

Severinghaus, W.D., W.D. Goran, G.D. Schnell, and F.L. Johnson, *Effects of Tactical Vehicle Activity on the Mammals, Birds, and Vegetation at Fort Hood, TX*, 22 pp, USACERL Technical Report N-113, September 1981. ADA109646.

Describes preliminary indications of ecological differences between select areas used for vehicle training and areas undisturbed by training, documents the procedures used to obtain this information, analyzes Fort Hood's ecosystem to verify the effects of training activities on ecosystems examined in previous research.

Severinghaus, W.D., R.E. Riggins and W.D. Goran, *Effects of Tracked Vehicle Activity on Terrestrial Mammals, Birds, and Vegetation at Fort Knox, KY*, USACERL Special Report N-77, July 1979. ADA073782.

Intensive studies were done at Fort Knox, Kentucky, at three sites representative of a long-term training area, a short-term training area, and a control area. This report describes the survey procedures used and provides preliminary indications of ecological differences between Army tracked vehicle training areas and areas representing pre-training (no-training) conditions.

Shaw, R.B., and V.E. Diersing. "Seasonal variation in vegetation cover estimates used in the USLE." Presented at the annual meeting of the American Society of Agronomy, Las Vegas, NV, *Agronomy Abstracts*, October 1989. p 9.

Shaw, R.B., M.J. Castillo, and D.G. Kowalski. Vegetation of the Pohakuloa Training Area, Hawaii. Amer. Soc. of Agron. 86th Annual Meeting. Seattle, WA. November 1994.

Shaw, R.B., R.D. Laven, and D.J. Tazik. Mitigation measures for endangered species on the Pohakuloa Training Area, Hawaii. Presented at the annual meeting of the ASA-CSSA-SSSA, San Antonio, TX, *Agronomy Abstracts*, October, 1990, p11.

Shaw, R.B., S.L. Anderson, K.A. Schulz, and V.E. Diersing. 1989. *Plant Communities, Ecological Checklist, and Sprcies List for the U.S. Army Pinon Canyon Maneuver Site, Colorado.* Colorado State University Department of Range Science, Science Series No. 37. 71 pp.

Presents an overview of the 244,000 acre Pinon Canyon Maneuver Site. Identifies and characterizes 26 plant communities, and includes a checklist of the 359 species found.

Zhuang, H.C., M. Shapiro, and C.F. Bagley. 1993. "Relaxation vegetation index in non-linear modelling of ground plant cover by satellite remote-sensing data." *Int. J.Remote Sensing*. Vol 14(18):3447-3470.

Area 3: Measurement and Characterization of Wildlife

Professional management of wildlife resources on Army lands can largely be attributed to the Sikes Act of 1960. This landmark act required military installations enter into cooperative management agreements with the U.S. Fish and Wildlife Service and the state wildlife agency, authorized the sale of installation hunting/fishing permits, and requiring the revenue from permit sales to be used exclusively on fish and wildlife management. Much of the management priority prior to and immediately following the Sikes Act was focused on game species and the concept of sustained yield, small-scale habitat manipulations to increase habitat interspersion and food availability, and other "traditional" management practices. Recent revisions to the Sikes Act and Army Regulation 200-3 (*Natural Resources—Land, Forest, and Wildlife Management*) indicate the Army's intent to incorporate, when practicable, the conservation of biological diversity through a multiple-species, ecosystem-level approach. Supporting this shift towards a broader management approach, USACERL undertook a number of projects designed to ascertain the status of various nongame wildlife populations, elucidate impacts from current military training activities, and provide the framework for improved data collection and management capabilities.

USACERL efforts to standardized the collection of wildlife data on training lands were initiated in the early 1980's to establish a common basis by which to characterize wildlife resources, aid in upward reporting, and promote inter-installation sharing of data. Recognizing the need to identify and predict site-specific, cause and effect relationships based on cost-effective data collection methods, Severinghaus, Diersing, and Lacey (1986) developed a set of standard methods for collecting bird and small mammal data based on the ecological guild theory. This initial effort was augmented by USACERL's development of a more generalized wildlife characterization and monitoring program associated with the Land Condition Trend Analysis (LCTA) program (Tazik et al. 1992). LCTA wildlife studies, initiated in 1989, are less site-intensive than that suggested by Severinghaus, Diersing, and Lacey (1986), and provide minimal but long-term installation-wide measures of presence, relative abundance, and diversity on selected terrestrial vertebrate groups. A recent series of manuals (Mitchell and Hughes) prepared by the CEWES forms Part 6.2, Vegetation Sampling, of the Corps of Engineers Wildlife Resources Management manuals. They give brief descriptions of the standard techniques used to characterize the vegetation component of wildlife habitat.

In today's economic climate, continued adherence to The National Environmental Policy Act (NEPA) and numerous Federal/state wildlife regulations is becoming increasingly important in order to avoid serious delays or even cessation of training activities on remaining Army lands. Off-road activities associated with military tactical vehicles are of special concern as they can seriously damage the vegetation, and if unmitigated, lead to excessive soil erosion. USACERL investigations into the effects of tracked and other vehicles at sites such as Fort Hood, Texas (Severinghaus et al. 1981), Fort Lewis, Washington (Severinghaus and Goran 1981), and Fort Knox, Kentucky (Severinghaus, Riggins, and Goran 1979) further confirms that mechanical disturbance of the soil and vegetation structure markedly influences wildlife in both species abundance and in community composition.

Occasionally, as in Balbach (1975) and Krzysik (1987), wildlife out of human control may become the focus of an intensive study. In both cases, bird roosts were causing health, aesthetic, and economic impacts in areas of intensive human use. More common is the need for continued documentation of environmental impacts associated with Army training activities on wildlife population and community structure. This focus, begun in the early 1980s, remains a critical information need identified by present-day Army land managers tasked with developing cooperative (integrated) natural resource plans, threatened and endangered species management plans, and increasing scrutinized NEPA-related documents such as Environmental Impact Statements (EIS), Environmental Assessments (EA), and Biological Assessments (BA).

3A: Applicable Results

Diersing, V.E., and W.D. Severinghaus, *Wildlife as an Indicator of Site Quality and Site Trafficability During Army Training Maneuvers*, USACERL Technical Report N-86/03, December 1985. ADA163560.

Report on field studies on four prairies on Pinon Canyon Maneuver Site and Fort Carson, CO, during May-June 1983 to compare relationship of soils and vegetation to bird and mammal species composition and abundance. Results suggest that the estimation of the numbers of each species on semiarid maneuver lands may be an effective management tool for installation land management.

Mitchell, W., and H.G. Hughes, *Point Sampling. Section 6.2.1, U.S. Army Corps of Engineers Wildlife Resources Management Manual*, CEWES Technical Report EL-95-25, July 1995, 22pp + app. ADA299921.

Description of the use of the point frame and the step-point techniques to sample groundcover vegetation for frequency, density, groundcover proportions. One of a series of manuals placed in Part 6.2, Vegetation Sampling, of the Corps of Engineers Wildlife Resources Management manuals.

Mitchell, W., and H.G. Hughes, *Line Intercept. Section 6.2.5, U.S. Army Corps of Engineers Wildlife Resources Management Manual*,CEWES Technical Report EL-95-22, July 1995, 17pp + app. ADA299915.

Description of the use of the line-intercept technique to sample shrubs and other rangeland vegetation for frequency, density, cover proportions. Examines cases where canopy is within intercept, but stems are not, a common problem area for many persons. One of a series of manuals placed in Part 6.2, Vegetation Sampling, of the Corps of Engineers Wildlife Resources Management manuals.

Mitchell, W., and H.G. Hughes, *Visual Obstruction. Section 6.2.6, U.S. Army Corps of Engineers Wildlife Resources Management Manual*, CEWES Technical Report EL-95-23, July 1995, 16pp + app. ADA299564.

Description of the use of the visual obstruction technique to sample forest understory and oldfield communities for horizontal cover. This factor is a measure of vegetation, but results are applied largely toward estimates of habitat suitability for wildlife species known to be affected by the presence or absence of sight lines. One of a series of manuals placed in Part 6.2, Vegetation Sampling, of the Corps of Engineers Wildlife Resources Management manuals.

Mitchell, W., H.G. Hughes, and L.E. Marcy, *Prism Sampling. Section 6.2.3, U.S. Army Corps of Engineers Wildlife Resources Management Manual*, CEWES Technical Report EL-95-24, July 1995, 32pp + app. ADA299918.

Description of the use of the wedge prism to sample forested areas for tree density, basal area, and timber volume. Designed for use in characterization of wildlife habitat. One of a series of manuals placed in Part 6.2, Vegetation Sampling, of the Corps of Engineers Wildlife Resources Management manuals.

Severinghaus, W.D., *Effects of Tracked Vehicle Activity on Higher Vertebrate Populations at Army Installations*, USACERL Technical Manuscript N-177, April 1984. ADA142653.

A reprint of two published papers (Severinghaus and Severinghaus 1982; Severinghaus, W.D., R.E. Riggins and W.D. Goran 1980) focusing on birds and small mammals as indicator groups.

Severinghaus, W.D., ed., *Proceedings: NATO CCMS Seminar Blue Book 159, Preservation of Flora and Fauna in Military Training Areas*, Conference Proceedings N-87/09, January 1987. ADA179754.

Severinghaus, W.D., and M.C. Severinghaus, "Effects of Tracked Vehicle Activity on Bird Populations," *Environmental Management*, 6(2):163-169, 1982.

Based on the ecological guild approach, this study identifies cause and effect relationships between Army impacts and avian guild composition and biomass.

Severinghaus, W.D., V.E. Diersing, and Robert M. Lacey, *Standard Methods for Ecological Survey of Army Training Lands: Site Selection, Disturbance Index, Bird and Mammal Data Collection*, USACERL Interim Report N-86/10, March 1986. ADA196571.

Documents the development of standard methods for conduction ecological studies on U.S. Army training lands. These methods are applicable to site selection, soil/vegetative disturbance indices, songbirds, and small mammals. Standard method would allow data gathered to be compatible at all installations.

Severinghaus, W.D., W.D. Goran, G.D. Schnell, and F.L. Johnson, "Effects of Tactical Vehicle Activity on the Mammals, Birds, and Vegetation at Fort Hood, TX", 22 pp, USACERL Technical Report N-113, September 1981. ADA109646.

Describes preliminary indications of ecological differences between select areas used for vehicle training and areas undisturbed by training, documents the procedures used to obtain this information, analyzes Fort Hood's ecosystem to verify the effects of training activities on ecosystems examined in previous research.

Severinghaus, W.D., R.E. Riggins, and W.D. Goran, *Effects of Tracked Vehicle Activity on Terrestrial Mammals, Birds, and Vegetation at Fort Knox, KY*, USACERL Special Report N-77, July 1979. ADA073782.

Intensive studies were done at Fort Knox, Kentucky, at three sites representative of a long-term training area, a short-term training area, and a control area. This report describes the survey procedures used and provides preliminary indications of ecological differences between Army tracked vehicle training areas and areas representing pre-training (no-training) conditions.

Severinghaus, W.D., R.E. Riggins, and W.D. Goran, "Effects of Tracked Vehicle Activity on Terrestrial Mammals and Birds at Fort Knox, KY," *Transactions of the Kentucky Academy of Science*, vol 41 (1980), pp 15-26.

Describes survey procedures and preliminary indications of population differences between pre- and post-treatment conditions.

Tazik, David J., *Effects of Army Training Activities on Bird Communities at the Pinon Canyon Maneuver Site, Colorado*, USACERL Technical Report N-91/31, Sep 1991. ADA248482.

Describes a study conducted at the Pinon Canyon Maneuver Site, CO, which investigated species habitat relationships of and impacts of Army training activities on avian communities in shortgrass prairie and pinyon-juniper woodlands. The study also identified wildlife indicators of habitat change using both species and guild approaches.

Tazik, D.J., William D. Severinghaus, and Victor E. Diersing, "Annual Variation in Populations of Birds and Small Mammals on an Army Installation," USACERL Interim Report N-86/02, December 1985. ADA164631.

Field studies at Fort Carson, CO, document annual variations in bird and small mammal populations on shortgrass prairie and pinyon-juniper woodland study sites. Results showed nonsignificant changes, concluding the population fluctuations are not related to training activities.

Whitworth, W.R., *Abundance, Distribution, and Selected Characteristics of Nesting Raptors on the Fort Sill Military Reservation, 1987 to 1992*, USACERL Technical Report 95/45, September 1995.

Six-year study in Oklahoma emphasizing Red-tailed Hawk, Red-shouldered Hawk, and Great Horned Owl nest distributions. Results suggest raptor habituation to military activities, abundance of potential nest sites, and micro- and macro-habitat preferences.

3B: Underlying Research Information

Balbach, Harold E., *Final Environmental Impact Statement - Blackbird Control on Two Army Installations*, USACERL, January 1975, 245 pp.

NEPA assessment of a problem deemed critical by the Army. Millions of blackbirds established a winter roost adjacent to family housing areas at Fort Campbell, KY/TN as well as at Milan AAP, TN. It was proposed to treat the roosts at night with a detergent spray in the belief that loss of body heat would reduce bird populations. Prepared under special emergency EIS rules, the Draft was prepared in 12 days and the Final EIS in 30 days. A supplement (see section Area 10B) was prepared to address late public comments, and the courts allowed the action to be performed.

Bathgate, Jon D., Calvin F. Bagley, Alison Hill, and David J. Tazik, "Biodiversity Management on Southeastern U.S. Military Installations: a GIS solution," *90th Annual Meeting of the Association of American Geographers*, San Francisco, CA, Mar 94 (*poster*).

Hayden, T.J., J.F. Faaborg, and R.L. Clawson, "Estimates of Minimum Area Requirements for Missouri Forest Birds," *Transactions, Missouri Academy of Sciences*, No. 19 (1985), pp 11-22.

Jorgensen, E.E., S. Demarais, and S. Neff, "Rodent Use of Microhabitat Patches in Desert Arroyos," *American Midland Naturalist*, vol 134 (1995), pp 193-199.

A 2-year study conducted at Fort Bliss, Texas/New Mexico, which is located in the northern portion of the Chihuahuan Desert.

Jorgensen, E.E., S. Demarais, and W.R. Whitworth, "The Effect of Box Trap Design on Rodent Captures," *The Southwestern Naturalist*, vol 39 (1994), pp 291-294.

A study comparing the relative effectiveness of the Sherman and a mesh-type live trap for small mammal studies in the arid southwest.

Kozma, J., and N.E. Mathews, "Cooperative Nesting Between Barn Swallows and Say's Phoebes in South-Central New Mexico," *The Auk*, vol 112 (1995), p 29.

Describes an unusual type of nesting arrangement between two avian species observed at Fort Bliss, TX/NM.

Krzysik, A.J. 1984. "Habitat relationships and the effects of environmental impacts on the bird and small mammal communities of the central Mojave Desert" in W.C. McComb, ed., *Proceedings - Workshop On Management of Nongame Species and Ecological Communities.* University of Kentucky, Lexington, Kentucky, pp 358-394.

Krzysik, A.J., *A Review of Bird Pests and Their Management*, USACERL Technical Report REMR-EM-1, September 1987. ADA190195. 145pp.

Krzysik, A.J., *Evaluation of Bird Pest Problems at U.S. Army Corps of Engineers Civil Works Projects*, USACERL Technical Report REMR-EM-2, September 1987. ADA191173. 54 pp.

Krzysik, A.J., *Birds in Human Modified Environments and Bird Damage Control: Social, Economic, and Health Implications*, USACERL Technical Report N-90/03, December 1989. ADA218043.

Severinghaus, W.D., Closing Remarks "Conference on the Applications of the Guild Concept to Environmental Management," USACERL Technical Manuscript N-86/07, February 1986. ADA167190.

Severinghaus, W.D., and W.D. Goran, *Effects of Tactical Vehicle Activity on the Mammals, Birds, and Vegetation at Fort Lewis, WA*, 45 pp, USACERL Technical Report N-116, Nov 1981. ADA111201.

Describes preliminary indications of ecological differences between select areas used for vehicle training and areas undisturbed by training, documents the procedures used to obtain this information, and analyzes Fort Lewis' ecosystem to verify the effects of training activities on ecosystems examined in previous research.

Tazik, David J., William D. Severinghaus, and Victor E. Diersing, *Annual Variation in Populations of Birds and Small Mammals on an Army Installation*, USACERL Interim Report N-86/02, Dec 1985. ADA164631.

Field studies report at Fort Carson, CO, to determine annual variations in bird and small mammal populations on shortgrass prairie and pinyon-juniper woodland study sites. Results showed some change, but concludes that the fluctuations in population are not related to training activities.

Tazik, D.J., S.D. Warren, V.E. Diersing, R.B. Shaw, R.J. Brozka, C.F. Bagley, and W.R. Whitworth, *U.S. Army Land Condition-Trend Analysis (LCTA) Plot Inventory Field Methods*, USACERL Technical Report N-92/03, February 1992, 63 pp. ADA247931.

Outlines standard methods for collecting and maintaining a permanent LCTA data base on the condition of Army land resources. LCTA uses standard methods to collect, analyze, and report natural resources data, and is the Army's standard for land inventory and monitoring. Included in the report are lists of equipment needed for data collection, and detailed procedures for establishing permanent field plots, collecting plant specimens, inventorying wildlife populations and maintaining the data bases by periodic short and long-term monitoring of the field plots.

Area 4: Characterization of Soils, Erosion, and Erosion Protection

Development of training land management guidance started at USACERL in 1977 as a means to mitigate environmental impacts through the development of guidance to preserve natural resources. The guidance documented procedures for incorporating environmental and natural resources considerations into the process of choosing sites for tactical vehicle training. Soil erodability was an important consideration. Training land use requirements were identified and conflicts between training and natural resources management were determined. Techniques were also identified for lessening the impact of training.

Most of the conflicts between training and natural resources management related to incompatible land uses such as other training uses, adjacent land use, unsafe areas, cultural resources, fragile soils, and sensitive natural resources. Conflict areas included land use, noise, unsuitable terrain, soils, dust, water quality, vegetation, and wildlife. General mitigation techniques were suggested, such as limiting the boundaries, scope, and timing of training activity. Revegetation was the principal mitigation technique suggested.

Major work on training area maintenance began in 1983. Increased intensity of training activity and continuing degradation of training lands was becoming recognized. Significant reduction in the availability of realistic training lands was a danger because land was being lost due to excessive soil erosion. The concept of land rehabilitation and maintenance was introduced through an overview of potential methods for maintaining training land in arid and semi-arid environments. The methods were directed primarily towards revegetation and control of erosion, although maintenance of trails was also covered. Land rehabilitation and maintenance programs at several installations were initiated.

Research was initiated in the early 1980's to develop a physical process model that would effectively and efficiently predict water and sediment yield in small, ungaged watersheds such as those typically found on military installations. Such a model, called MULTSED, had been developed by Colorado State University for the U.S. Forest Service. This model was adapted for use at military installations and was renamed ARMSED. Although never widely used at the installation level, ARMSED has continued to be used in support of ongoing research and development (R&D) activities. Current initiatives related to predicting erosion are focusing on models built to operate within the framework of geographic information systems.

In 1985, a demonstration of land rehabilitation was initiated at Fort Carson under the Facilities Technology Application Testing (FTAT) program. After three growing seasons the feasibility of repairing severely degraded land was proven. A 1990 report documented a return-on-investment study of the Fort Carson field test which verified the economic benefits that could be obtained. A demonstration at Hohenfels, Federal Republic of Germany was also initiated in 1985 and helped to reinforce the value of land rehabilitation.

Revegetation studies continued through 1989 emphasizing agronomic/reforestation methods. In 1987, work was initiated to develop physical/structural methods for erosion control. Erosion control emerged as the principal focus of land rehabilitation and maintenance development activity. Reimbursable work began to test and evaluate erosion control methods at selected installations.

In 1989, the concept of tactical concealment islands was introduced through a demonstration project at Fort Riley under the FTAT program. From 1989 to 1993 the principal research topics were vegetative species selection, structural erosion control, and tactical concealment islands and corridors.

Guidance for erosion control management planning was documented in a 1990 report. The guidance emphasized watershed-scale planning for erosion control. It also outlined procedures for site evaluation, assessment of erosion control needs, project development, and incorporation of erosion control projects into an installation's annual work plan.

Three Universities have been significantly involved in USACERL research on a variety of topics related to soils, erosion prediction and erosion control. Dr. Timmothy Ward, New Mexico State University, developed ARMSED, a water and sediment yield prediction model. Dr. Harry Wenzel, University of Illinois, conducted testing and evaluation of ARMSED, and made comparisons with other erosion prediction models. Dr. Kent Mitchell, also at the University of Illinois, has been and continues to be involved in field evaluations and demonstations of erosion control technologies. Dr. Bernie Engle, Purdue University, has been and continues to be involved in monitoring water quality to determine the effectiveness of erosion control methods.

4A: Applicable Results

Diersing, V.E., E.W. Novak, and H.E. Balbach, "A Method for Calculating Allowable Use of Tracked Vehicles on US Army Maneuver Lands," *Agronomy Abstracts, 1985 Annual Meetings of the American Society of Agronomy*, December 1985. p.40

Gebhart, Dick L., and Steven D. Warren. *Regional Cost Estimates for Rehabilitation and Maintenance Practices on Army Training Lands*, USACERL Technical Report 96/02, October 1995. ADA303360.

Summarizes current regional cost data for performing typical land rehabilitation actions such as surface grading, seeding, and fertilizing. Presents data arranged by seven regions of the United States, and includes the regional average as well as the range for each practice. An appendix lists 75 original sources from which these data were obtained.

Riggins, Robert E., and L.J. Schmitt, "Development of Prediction Techniques for Soil Loss and Sediment Transport at Army Training Lands," USACERL Technical Report N-181, June 1984. ADA144110.

Describes the selection of analytical techniques for predicting physical land degradation that results from training activities at Army installations. The techniques judged suitable for predicting physical degradation to Army lands will then be integrated into a comprehensive computer based analytic tool for use at Army installations.

Riggins, Robert E., T.J. Ward, and W. Hodge, *ARMSED, A Runoff and Sediment Yield Model for Army Training Land, Watershed Management Volume I: Parameter Estimation*, USACERL ADP Report N-89/12, Vol I, Aug 1989. ADA212969.

Provides instruction and documentation for Army Multiple watershed storm water and sediment runoff (ARMSED) simulation model based on the MULTSED model. ARMSED is used to estimate runoff and sediment yield from small ungaged watersheds on Army training lands to assess the condition of the lands and to evaluate alternative erosion control plans. Volume I describes selecting and estimating the parameters and values needed as input. Volume II describes various subroutines and version modifications.

Riggins, Robert E., W. Hodge, R.M. Lacey, and T.J. Ward, *Sediment Control at Army Training Areas Case Study: Hohenfels, Federal Republic of Germany*, USACERL Technical Report N-89/08, April 1989. ADA207366.

Study conducted at the Hohenfels Training Area, Federal Republic of Germany, to evaluate the existing sediment control network and to make recommendations for rehabilitation of damaged check dams. Data gathered was used in the ARMSED model to simulate the results of various activities and improvements.

Thompson, Pamela, W.D. Goran, and Maury Mausbach, 1987, "An Interactive Soils Information System," *Agronomy Abstracts*, American Society of Agronomy 1987 Annual Meeting, Atlanta, GA, Nov 1987.

Thompson, Pamela, K. Young, W. Goran, and A. Moy, "Interactive Soils Information System User's Manual," USACERL Technical Report N-87/18, July 1987. ADA185153.

U.S. Army Technical Manual (TM) 5-631, Appendix G, *Off-Road Vehicle Site Selection*, January 1984.

Vachta, E.G., and R.E. Riggins, *Erosion Control Management Plan for Army Training Lands*, USACERL Technical Report N-90/11, July 1990. ADA226558.

Describes the Erosion Control Management Plan (ECMP), which offers procedures to accurately identify erosion problems, assess needs, select appropriate solutions, and compare the costs of alternatives. The ECMP is part of the Integrated Training Area Management (ITAM) program, which provides guidance for reducing soil erosion, resource loss, stream pollution, and offsite sedimentation.

Vachta, E.G., and R.E. Riggins, *Erosion Control Methods for Army Training Land Rehabilitation: Survey of Current Technology*, USACERL Technical Report N-88/05, May 1988. ADA197566.

A comprehensive summary of erosion control technology which classifies and briefly discusses current methods, materials, and structures. Erosion control measures are classified according to their role in disrupting erosion: soil stabilization, runoff management, and sediment control.

Warren, Steven D., Victor E. Diersing, W.D. Goran, and Pamela J. Thompson, 1989, "An Erosion-Based Land Classification System for Military Installations," *Environmental Management*, Vol 13, No. 2, pp 251-257, Spring 1989.

Warren, Steven D., Victor E. Diersing, Pamela J. Thompson, and William D. Goran, *An Erosion-Based Land Classification System for Military Installations*, USACERL Technical Manuscript N-91/05, Feb 1991. ADA232444.

Describes a land classification system for use by military trainers and land managers to minimize the environmental impacts of military training activities. This system uses the universal soil loss equation (USLE) integrated with the Geographic Resources Analysis Support System (GRASS).

Zellmer, S.D., R.R. Hinchman, R.P. Carter, W.D. Severinghaus, R.M. Lacey, and J.J. Brent, *Documentation of the Range 8C Rehabilitation Demonstration Project at Hohenfels Training Area, West Germany*, Argonne National Laboratory Report ANL/ESD/TM-26, March 1987.

4B: Underlying Research Information

Dubois, P.C., and S.D. Warren, "Estimating Soil Loss on Military Installations using the Universal Soil Loss Equation," presented at the Second Annual Meeting, International Association for Impact Assessment, Champaign, Illinois. June 1991.

Dubois, P.C., *Impacts on Soils and Vegetation at Yakima Training Center, Washington, from the Proposed Stationing of Mechanized or Armored Combat Forces.* Unpublished USACERL Report, 1993, in Environmental Impact Statement, Stationing of Mechanized or Armored Combat Forces at Fort Lewis, Washington, September 1993.

Ellerbroek, J.W., B.C. Yen, and R.E. Riggins, "Effect of Data Sampling Time Resolution on Probability Distribution of Elapsed Time Between Rainfalls," *Proceedings of ASCE Conference on Irrigation and Drainage Engineering*, Buffalo, NY, July 1994.

Foltz, Randy B., Application of a Snowmelt and Rainfall-Runoff Model to New Mexico Watersheds. May 1987. Master of Science in Civil Engineering Thesis submitted to New Mexico State University. [Enhancement of the ARMSED model.]

Lacey, R.M., and H. Balbach, *Evaluation of Areas for Off-Road Recreational Motorcycle Use Volume II: Alternate Soil Suitability Determination Methods*, USACERL Technical Report N-86, November 1980. ADA096528.

Volume II describes seven alternative methods for evaluating soil suitability for trailbike use, including simplified laboratory techniques.

Lacey, Robert M., D. McCormack, and D. Slusher, "Guide for Rating Soil Limitations for Off-Road Vehicle Trails," *National Soil Handbook, Part II* (U.S. Department of Agriculture, Soil Conservation Service, April 1979), Section 403.6 (D).

Melching, C.S., C. Ben Yen, H.G. Wenzel, 1991, "Output reliability as guide for selection of rainfall-runoff models," *J. Water Resources Planning and Management*, 117:383-398.

Riggins, Robert E., and J.T. Bandy, "Predicting Erosion at Army Military Installations," ASCE Water Forum '81 Conference, Aug 1981.

Riggins, Robert E., and J.T. Bandy, *R-Factors for Soil Loss Impact Prediction*, USACERL Technical Manuscript N-125, March 1982. ADA112872.

Documents a procedure that has been developed for determining design R-values for use in soil-loss impact analysis. The procedure brings together a new, more simple method of calculating R-values, the concept of simple risk and readily available precipitation data. The procedure was tested using precipitation data from stations in Texas and Georgia. The R-values determined using this procedure follow a log-normal probability distribution and can be adjusted to be comparable with published R-values in Agricultural Handbook No. 537.

Riggins, Robert E., and J.T. Bandy, "R-Factors for Soil Loss Impact Prediction," *J. Envir. Engr. Division*, ASCE, Vol 107, No EE4, Aug 1981.

Riggins, Robert E., T.J. Ward, and W. Hodge, *ARMSED, A Runoff and Sediment Yield Model for Army Training Land Watershed Management Vólume II: Program Documentation*, USACERL ADP Report N-89/12, Vol II, Aug 1989. ADA212926.

Provides instruction and documentation for Army Multiple watershed storm water and sediment runoff (ARMSED) simulation model based on the MULTSED model. ARMSED is used to estimate runoff and sediment yield from small ungaged watersheds on Army training lands to assess the condition of the lands and to evaluate alternative erosion control plans. Volume I describes selecting and estimating the parameters and values needed as input. Volume II describes various subroutines and version modifications.

Seiger, A.D., Application of a Small Area Rainfall Simulator to Soil Erosion Studies at Pinon Canyon, Colorado. June 1984. Master of Science in Civil Engineering Thesis submitted to New Mexico State University.

Vachta, E.G., and J. Hutchinson, *Pilot and Expanded Field Testing of the Erosion Control Management Plan (ECMP) for Army Training Lands: Lessons Learned*, USACERL Technical Report N-91/04, Dec 1990. ADA231920.

Presents a summary of lessons learned during pilot and expanded distribution and field testing of ECMP. It presents difficulties encountered, successes realized, and the logical progression of events that has defined ECMP's applicability. ECMP is a logical and standard process to help installation land managers plan, select, and implement erosion controls. It is the erosion control component of ITAM.

Vaughn, C.C., G.D. Schnell, and R.E. Riggins, *Feasibility of Using Rational Threshold Values to Predict Sediment Impacts from Army Training*, USACERL Technical Report N-153, June 1983. ADA130997.

Summarizes research on the feasibility of using Rational Threshold Values to predict sediment related impacts in Army training areas. The information will be useful to Army land managers who program training area maintenance.

Warren, S., G. Howard, and S. White, *Sources of Plant Materials for Land Rehabilitation*, USACERL Special Report EN-95/01, Dec 1994. ADA291934.

Land rehabilitation and maintenance must be performed to minimize environmental degradation and improve the safety and realism of the training mission. One step in the rehabilitation and maintenance process is to purchase appropriate plant materials, particularly locally endemic or adapted species. This report offers a list of plant material vendors in each state that may then be contacted by managers and trainers for solicitation of bids.

Wenzel, H.G., and C.S. Melching, *Evaluation of the MULTSED Simulation Model to Predict Sediment Yield*, USACERL Technical Report N-87/27, Sep 1987. ADA185615.

Area 5: General Land Management Issues

The science of land management is an amalgam of skills and experience that must be drawn from multiple disciplines. At one time, agronomists, foresters, wildlife biologists, recreation managers, cultural resource managers, and planners each were responsible for portions of the environment on a typical military installation. This separation of knowledge and responsibility is no longer viewed as a good management strategy. Each person must know of, and appreciate, the responsibilities of each of the others. In particular, the management of the test and training areas, those thousands of acres of "un-built" environment, may well be more complex than management of the installation infrastructure facilities, which have traditionally received much greater attention and priority.

Within this chapter are grouped references that treat multiple aspects of environmental assessment and management, frequently in an interdisciplinary or cross-disciplinary manner. The use of the self-audit as an internal measure of quality is one of these processes. Other areas of focus are the need for coordination among local, state, and Federal regulatory personnel, and the consideration of military test and training effects on the lands in question. Cross-disciplinary areas such as noise, land use planning, and the integration of environmental considerations into project development are also found here. Many of the following citations have been incorporated in other sections of this bibliography as well as under this heading.

5A: Applicable Results

Balbach, Harold E., Natural Resources Management Self Audits in *Protocol: Environmental Self-Audit Program*, Army Environmental Hygiene Agency Report 43-21-1316-86. November 1985.

A 15-page self-audit protocol developed for application at all Army installations within the Chesapeake Bay drainage as a part of the Army's responsibilities under the Chesapeake Bay Initiative. Covers most land management activities as well as cultural resources.

Balbach, Harold E., "Natural Resources Management Self Audits: Form and Function," *Agronomy Abstracts, 1987 Annual Meetings of the American Society of Agronomy*, November 1987.

Self-audit procedure for application by military installation to discover their strong and weak management areas. Includes an evaluation guide to help interpret the answers.

Balbach, Harold E., R. Lacey, and J. Fittipaldi, *Compendium of Administrators of Land Use and Related Programs*, USACERL Technical Report N-40, July 1978. ADA057226.

More than 1,000 names, addresses, and phone numbers for Federal and state-level oversight personnel with responsibility for certain programs, such as air quality, water quality, land use planning, transportation planning, etc. Designed for use by installation planners for use in project coordination at the local level. (Revised in 1982, see Engelman, et al., following.)

Balbach, Harold E., W. Severinghaus, and R. Lee, "Use of Integrated Training Area Management Procedures as Mitigation and Impact Avoidance within the EIS Process," *Agronomy Abstracts, 1992 Annual Meetings of the American Society of Agronomy*, November 1992. p 9.

Baran, R.S., L.A. Engelman, R.G. Goettel, and W.D. Severinghaus, *An Overview of Potential Methods for Maintaining Training Area Environments in Arid and Semi-Arid Climates,"* USACERL Technical Report N-139, April 1983, 146 pp. ADA130075.

Presents a general overview of several techniques and types of equipment that can be used for land maintenance in the arid and semi-arid regions of the United States. This will help to maintain effectiveness of training and realism in training atmosphere of the area. The report will also allow users to develop a land maintenance field-testing program at the local level.

Bern, C.M., and R.B. Shaw (eds). 1993. Maintenance and Repair of Military Training Lands. A National Symposium. Center for Ecological Management of Military Lands, Colorado State University, Fort Collins, CO. Technical Publication Series 93-1.

Diersing, V.E., S.D. Warren, C.F. Bagley, and R.B. Shaw. *Management Options for Mitigating Natural Resource Training Impacts on Army Installations*, USACERL Technical Report N-90/12, June 1990, 146 pp. ADA224891.

A checklist of management actions that can streamline the decision-making process and increase the likelihood that managers will consider the full range of alternative actions.

Diersing, V.E., E.W. Novak, and H.E. Balbach, "A Method for Calculating Allowable Use of Tracked Vehicles on US Army Maneuver Lands," *Agronomy Abstracts, 1985 Annual Meetings of the American Society of Agronomy*, December 1985. p 40.

Diersing, V.E., R.B. Shaw, S.D. Warren, and E.W. Novak. 1989. "A user's guide for estimating allowable use of tracked vehicles on nonwooded military training lands," *J. Soil Water Conserv.* 43(2):191-195.

Describes a method to avoid excessive soil erosion and ensure the continued availability of U.S. military training lands by establishing a basis for estimating allowable levels of sustained tracked vehicle use. The information gathered can be used to estimate maximum allowable use for each ecological response unit. Land managers can then verify that allowable use is not exceeded by measuring the percentage of the surface that appears tracked. Adjustments in allowable use are based on trends in the amount of ground cover and by observing changes in botanical composition.

Doerr, T.B. and M.C. Landin, *Recommended Species for Vegetative Stabilization of Training Lands in Arid and Semi-arid Environments*, USACERL Technical Report N-85/15, Sep 1985. ADA161551.

Identifies key plant species that may be useful to installation land managers seeking to maintain or rehabilitate training lands in arid and semi-arid environments. The plant species are described in terms of their regional and environmental adaptations, limitations, uses, establishment requirements, and availability. Recommendations for short and long term revegatation efforts are given for selected western installations.

Engelman, L.A., H. Balbach, J.J. Fittipaldi, and R.M. Lacey, *Compendium of Administrators of Land Use and Related Programs, Updated Edition*, USACERL Technical Report N-40, Sep 1982. ADA128413.

A compendium of the names, addresses, and telephone numbers of Federal agency and State government officials having control over, or interest in, land use, and plans and programs related to land use. Twenty categories of State-level programs are included, with one or more points of contact suggested for each state for each applicable type of program. Twenty-six Federal government categories are identified whose programs may require coordination with Army activities. (updated from 1978 Technical report N-40).

Fittipaldi, J.J., and Hottman, S.D.,"The Installation Compatible Use Zone (ICUZ) Program," *Environmental Impact Assessment Review*, Vol. 7, No. 3, Sep 1987, 14 pp.

Fittipaldi, J.J., *Procedures for Conducting Installation Compatible Use Zone (ICUZ) Studies*, USACERL Report N-88/19, Aug 1988. ADA200718.

Provides guidance to help Army installation environmental offices perform Installation Compatible Use Zone (ICUZ) studies. The purpose of the ICUZ Program is to protect the installation mission, as well as the public, by identifying noise-impacted areas so that concerned public local government and installation elements can work together to minimize noise-sensitive development. The report describes each step in detail of the 12 step ICUZ study process, and information is given to answer those questions most asked by those who use ICUZ studies.

Gebhart, Dick L., and Steven D. Warren. *Regional Cost Estimates for Rehabilitation and Maintenance Practices on Army Training Lands*, USACERL Technical Report 96/02, Oct 1995. ADA303360.

Summarizes current regional cost data for performing typical land rehabilitation actions such as surface grading, seeding, and fertilizing. Presents data arranged by seven regions of the United States, and includes the regional average as well as the range for each practice. An appendix lists 75 original sources from which these data were obtained.

Goettel, R.G., H. Balbach, and W.D. Severinghaus, *Guidelines for Installations Natural Resource Protection During Training*, USACERL Technical Report N-104, Oct 1981. ADA107987.

Describes how U.S. Army installation personnel can assemble material for a training package that explains how to protect an installation's natural resources. Suggested text and artwork have been regionalized to allow a reasonable approximation of the specific environments found on most Army installations. Included are explanations of how the appropriate regionalized sections of the package can be selected and reproduced. Instructions are also provided on how an installation specific map and information section can be prepared.

Herricks, E. E., A.J. Krzysik, and R.E. Szafoni. 1981. *An illustrated guide to selected fish and wildlife habitat development procedures*. Civil Engineering Studies, Environmental Engineering Series No. 63, UILU-ENG-81-2008.

Herricks, E.E., A.J. Krzysik, R.E. Szafoni, and D.J. Tazik. 1982. *Best current practices for fish and wildlife on surface-mined lands in the eastern interior coal region*. FWS/OBS-80/68. Fish and Wildlife Service, U.S. Department of the Interior. 212 pp.

Kaden, J., W. Goran, and H. Balbach, "Managing Agricultural Outleases on Military Installations," *Agronomy Abstracts, 1985 Annual Meetings of the American Society of Agronomy*, December 1985, p 90.

Kowalski, D.G, K.G. Landreth, and K.A. Majerus. 1992. Legacy Data Management Task Area Report to Congress. 28 pp.

Kowalski, D.G, K.G. Landreth, and R.S. Wade. 1993. Legacy Data Management Task Area Report to Congress. 96 pp.

Lacey, R.M., H.E. Balbach, and W.D. Severinghaus, "Site Selection Procedures for Tactical Vehicle Training Areas," *Agronomy Abstracts*, Amer. Soc. Agron., 1982, p 8.

Lacey, R.M., R.S. Baran, H.E. Balbach, R.G. Goettel, and W.D. Severinghaus, "Off-Road Vehicle Site Selection," *J. Environ. Sys.*, 12(2):113-140, 1982.

Lacey, Robert M., "Evaluation of Army Lands for Potential Trailbike Use," *Planning for Trailbike Recreation, Part II*, (U.S. Department of Interior, Heritage Conservation and Recreation Service, March 1981), pp 23-27.

Lacey, Robert M., and W.D. Severinghaus, *Evaluation of Lands for Off-Road Recreational Four-Wheel Drive Vehicle Use*, USACERL Technical Report N-110, Oct 1981. ADA108804.

Presents a method to evaluate land areas on Army installations for use by off-road recreational four-wheel drive vehicles. This method is designed to be as nontechnical as possible and while geared for military use it can be used for many public and private applications. The method describes how to identify incompatible land uses and noise conflict, choose candidate areas, evaluate soil and biological suitability, and develop trails. Also discussed are 4WD user participation, trail design, vehicle operation conditions, and environmental assessment and monitoring.

Lacey, Robert M., and W.D. Severinghaus, *Natural Resource Considerations for Tactical Vehicle Training Areas*, USACERL Technical Report N-106, June 1981. ADA103276.

Provides land evaluation criteria and procedures for incorporating environmental and natural resource considerations into the process of choosing sites for tactical vehicle training. Elements addressed include land use, noise, terrain, soil, air quality, water quality, vegetation, and wildlife. Procedures are suggested to lessen the impact of tactical vehicle training on these resources.

Lacey, Robert M., H. Balbach, R.G. Goettel, and W.D. Severinghaus, *Planning for Off-Road Recreational Vehicle Use on Army Installations*, USACERL Technical Report N-132, July 1982. ADA119313.

Looks at the results of USACERL's research conducted to help installation personal comply with the policies, procedures, and criteria of Army Regulation 210-9, *Use of Off-Road Vehicles on Army Lands*. The report is for use primarily by recreational planners and land management personnel. It describes a general process and some specific considerations for planning for off-road recreational vehicle use on Army Lands.

Mann, D.K., M. Messenger, R.D. Webster, D.P. Gerdes, M.E. Higgins, 1986, *The DEEP Knowledge-Based System*, USACERL Technical Report N-86/09, March 1986. ADA166863.

User guide for DEEP Knowledge-Based System. This program provides Army environmental personnel an easy way to share problems, ideas, solutions, and information on the latest proven technologies.

Marlatt, R.M., T.A. Hale, R.G. Sullivan, and R.M. Lacey, *Guidelines for Applying Video Simulation Technology to Training Land Design*, USACERL Technical Report EN-93/05, Feb 1993. ADA264980.

An instructional and reference manual designed to help Army land managers and trainers better apply video simulation technology to their land management activities. This is intended to help land managers communicate technical information in a simple form, easily understood by both technical and nontechnical persons, by visually simulating the effects of land management actions.

Messenger, Manette, *Protecting the Environment During Maintenance Activities*, 17 pages, soldiers' handbook, July 92.

Riggins, Robert E., S. Apfelbaum, W.D. Goran, A.J. Krzysik and T.J. Ward, *Development of Environmental Guidelines for Multipurpose Range Complexes Volume I: Application Test and Environmental Management Plan Development*, USACERL Technical Report N-87/02, Vol I, Jan 1987. ADA176255.

Riggins, Robert E., S. Apfelbaum, W.D. Goran, A.J. Krzysik and T.J. Ward, *Development of Environmental Guidelines for Multipurpose Range Complexes Volume II: Description of Field Tests, Sediment Yields, and Option Analysis*, USACERL Technical Report N-87/02, Vol II, Jan 1987. ADA176256.

Volume I describes the results of a demonstration test conducted at Fort Riley, KS, of various technologies developed to manage natural resources and reduce the effects of training activities from the new Multipurpose Range Complex (MPRC). The test results provided comprehensive data about the installations resources and the effects of training activities on them. Volume II provides details on the field tests, sediment yield study, and management option analysis.

Riggins, Robert E., and W.D. Goran, *Water Quality Data for Army Military Installations*, USACERL Technical Report N-63, Feb 1979. ADA067253.

Identifies major sources of water quality data and describes the location of sampling stations at or near selected Army military installations. This data summary is designed to help in successfully creating water quality models at Army military installations to perform environmental impact analysis.

Scholze, R.J., J.T. Bandy, W.P. Gardiner, W.H. Curley, and E.D. Smith, *Field Shower Wastewater Recycling System: Development of a Program of Instruction and Preliminary Analysis of its Potential Health Implications*, USACERL Technical Report N-87/07, Feb 1987. ADA178112.

Discusses the development of a suggested program of instruction for operators of a Field Shower Wastewater Recycling System (FSWRS) — a system designed to recycle water used in showers in the field. This report also identifies water quality test requirements and procedures to be used when recycling shower wastewater, and examines the health implications associated with water recycled by FSWRS.

Schomer, Paul D., "An Analysis of Community Complaints to Army Aircraft and Weapons Noise," *J. Acoust. Soc. Am.*, Vol. 73, No. 4, April 1983, p 1229-1235.

Schomer, Paul D., Assessment of Community Response to Impulsive Noise, *J. Acoust. Soc. Am.*, Vol 77, No. 2, Feb 1985, pp 520-535.

Severinghaus, W.D., "Integration of Natural Resource Conservation, Environmental Protection, and Training Realism," in *Proceedings: Conference on Applications of the Guild Concept to Environmental Management*, USACERL Technical Manuscript N-86/07, February 1986. ADA167190.

Severinghaus, W.D., "The Environment: A Tactical Advantage," *Army Trainer*, 1987, p 34-5.

Severinghaus, W.D., and E.W. Novak, "The Integrated Training Area Management (ITAM) Program," *Infantry*, 1987, p 8.

Shaw, R.B., and V.E. Diersing. 1989. "Allowable use estimates for tracked vehicular training on Pinon Canyon Maneuver Site, Colorado, USA," *Environ. Manage.* 13(6):773-782.

Shaw, R.B., R.D. Laven, and D.J. Tazik. "Mitigation measures for endangered species on the Pohakuloa Training Area, Hawaii," presented at the annual meeting of the ASA-CSSA-SSSA, San Antonio, TX, *Agronomy Abstracts*, Oct 1990. p 11.

Tazik, D.J., V.E. Diersing, S.D. Warren, C.F. Bagley, and R.B. Shaw, *Management Options for Mitigating Natural Resource Training Impacts on Army Installations*, USACERL Technical Report N-90/12, June 1990. ADA224891.

Serves as a checklist of management actions that can streamline the decision-making process and increase the likelihood that managers will consider the full range of alternative actions.

Tazik, David J., and Chester O. Martin, *U.S. Army Threatened and Endangered Species Research and Development Strategy and Action Plan*, USACERL Special Report EN-94/06, June 1994. ADA284207.

Serves as a checklist of management actions that can streamline the decision-making process and increase the likelihood that managers will consider the full range of alternative actions.

Tyler, E.H., W. Wheeler, and C. Lau, *Integration of Environmental Planning Into the Army Master Planning Process*, USACERL Technical Report EC-93/01, Oct 1992. ADA262586.

Examines integration of environmental planning into the Army installation master planning process within the AR 210-20 series. Suggests that short term crises may be minimized through comprehensive assessment of master plans at the programmatic level, with followon tiering of more specific actions. Automated tools and techniques that may be of use in this process are reviewed.

U.S. Army Technical Manual (TM) 5-631, Appendix G, *Off-Road Vehicle Site Selection*, January 1984.

Waring, M.R., J.W. Teaford, H.H. Allen, T.G. Goeller, K.L. Schultz, B.E.Davis, D.E. Evans, and T.D. Wray, *Fort Benning Land-Use Planning and Management Study*, CEWES Technical Report EL-90-4, April 1990, 105pp + app.

Documentation and results of a GIS-based environment and land use atudy of the Fort Benning, GA military reservation. Develops and applies a land-use planning methodology considering many aspects such as forestry, wildlife, soils, threatened species, and others. Appendices contain the decision flowchart used and results of the planning tools developed.

Warren, S.D., and S.G. Aschmann, *Revegetation Strategies for Kaho'olawe Island, Hawaii*, USACERL Technical Manuscript EN-94/02, March 1994. ADA278778.

Looks at the revegetation of Kaho'olawe, an island that had become mostly barren and severely eroded from war, slash-and-burn agriculture, and overgrazing. Treatments included drill seeding, jute netting, windbreak fencing, and fertilization. The report looks at what methods work best and which are the most cost effective.

Warren, Steven D., Victor E. Diersing, W.D. Goran, and Pamela J. Thompson, "An Erosion-Based Land Classification System for Military Installations," *Environmental Management*, Vol 13, No. 2, pp 251-257, Spring 1989.

Warren, Steven D., Victor E. Diersing, Pamela J. Thompson, and William D. Goran, *An Erosion-Based Land Classification System for Military Installations*, Feb 1991. USACERL Technical Manuscript N-91/05. ADA232444.

Describes a land classification system for use by military trainers and land managers to minimize the environmental impacts of military training activities. This system uses the universal soil loss equation (USLE) integrated with the Geographic Resources Analysis Support System (GRASS)

Zellmer, S.D., R.R. Hinchman, R.P. Carter, W.D. Severinghaus, R.M. Lacey, and J.J. Brent, *Documentation of the Range 8C Rehabilitation Demonstration Project at Hohenfels Training Area, West Germany*, Argonne National Laboratory Report ANL/ESD/TM-26, March 1987.

Zimmerman, R.E., D.O. Johnson, S.D. Zellmer, R.M. Lacey, and W.D. Severinghaus, "Return-On-Investment Case Study for the Rehabilitation of Training Areas Damaged by Tracked Vehicles as Fort Carson, Colorado", Amer. Soc. Agron., *Agron. Abstracts*, 1987, p 10.

5B: Underlying Research Information

Balbach, Harold E. with Bruce Dickson, *A Case Study of Coordinated Resource Management Programs at Selected Department of Defense Installations*, Legacy Resource Management Program Special Report; USACERL Technical Report CRC-95/01, Dec 1994, 40 pp. ADA289429.

Natural and cultural resources managers were identified by service headquarters as exemplary program managers. They were interviewed, both in person and by telephone, to identify common characteristics. In general, these managers: had good relationships with the command structure; were innovative in locating sources of funding; had established effective internal review of proposed projects so as to avoid conflicts; and maintained effective communication with on-site military and civilian managers.

Balbach, Harold E., T.A. Lewis, and R.D. Webster, *Environmental Management in the Master Planning Process a Methodology for Impact Avoidance,* USACERL Letter Report E-49, Sep 1974.

Presents the findings of research preformed to evaluate the ability of a land resource classification system to define areas susceptible to substantial environmental damage as a result of Army military training activities. The classification system uses sort data compiled by the U.S. Department of Agriculture, Soil Conservation Service (SCS) as the primary data input. Fort Riley, Kansas is used as a representative military installation.

Balbach, Harold E., with R. Lozar and J.R. Anderson, *Data Requirements for Army Land Use Planning and Management,* USACERL Interim Technical Report N-55, November 1978. ADA062599.

Looks at data surveyed and analyzed by the Department of the Army installation natural resources management and planning to aid compliance with existing and projected Army policies. The methodology used included a survey of the data requirements of 32 currently available analytical models and the data sources to supply input. The models covered areas such as soil erosion, flood susceptibility, groundwater pollution, watershed runoff, wildlife management, visual impact, agricultural productivity, forest management, air quality, water quality, and noise levels.

Bandy, J.T., and M. Messenger, *Procedure for Evaluating Subpotable Water Reuse Potential*, USACERL Technical Report N-109, November 1981, ADA111191.

Addresses the Wastewater Reuse component of the Pollution Abatement Management System (PAMS). This will help the Army to meet Federal environmental requirements by allowing a quick, accurate assessment of reuse potential, and providing a basis for economic comparison of reuse systems.

Baran, R.S., H. Balbach, W.D. Severinghaus, and D.J Hunt, *Overview of Considerations in Assessing the Biomass Potential of Army Installations,* USACERL Technical Report N-108, August 1981. ADA107132.

Provides Army installations an overview of necessary considerations for evaluating the feasibility of using forest resources (biomass) as an alternative source of fuel, identifies state-of-the-art land management techniques needed for biomass harvest and management, and provides a comprehensive annotated bibliography on biomass materials.

Belles, R.C., M.S. Larson, and R.C. Lozar, *Environmental Early Warning Systems (EEWS): Data Input Manual*. USACERL Technical Report N-87/03, Jan 1987. ADA178254.

Describes the methods for entering information to the EEWS data base, gives examples of manual input by a data-loading specialist, and describes automated loading procedures by a systems maintainer. EEWS is an interactive computer system designed to give planners and decision makers a way to quickly find potential environmental related problems associated with proposed changes in troop strength, mission, facilities, natural resource management, and land use.

Conrad, C.C., R.E. Riggins, and C.M. Foley, *Land For Combat Training, Phase I Report,* Army Environmental Policy Institute, AEPI-IFP-1, December 1994, 60pp.

An overview of the many pressures on the Army that are related to maintaining its base of training lands. Environmental regulations, including NEPA, the Endangered Species Act, the National Historic Preservation Act, and others, are each briefly discussed and the problems resulting from their application to Army lands are presented. The difficulty in calculating needs with any accuracy is also discussed, as are trends in environmental and military management processes.

Corbin, C., and J. Fittipaldi, *The Stationing Analysis Model (SAM): System Overview and Functional Description*, USACERL ADP Report N-187, August 1984.

Provides the formal systems documentation for the Army Stationing Analysis Model (SAM). SAM provides facility planners at HQDA, MACOMs, Engineer Divisions and Districts, and installations with a process to compare installation facilities assets with the demands of projected installation unit force structures, and thus be able to quickly and easily identify facility deficiencies. SAM has since evolved into the Real Property and Analysis System, RPLANS.

Diersing, V.E., J.A. Courson, S.D. Warren, D.J. Tazik, R.B. Shaw, and E.W. Novak. *Climatic basis for planning military training operations and land maintenance activities*, USACERL Technical Report N-90/13, June 1990. ADA224174.

Presents the results of an investigation of the utility of long-term precipitation and temperature data for military land-use planning. These data can then be used in the scheduling of major exercises and optimum rehabilitation schedules to reduce the risk of excessive environmental damage.

Fittipaldi, J.J., and S.E. Hottman, "A Microcomputer System for the Prediction of Blast Noise Impacts," *Noise Control Engineering Journal*, XXVI, No. 3, May-June 1989, 12 pp.

Goran, W.D., and R.E. Riggins, "Geographic Information Systems for Training Land Evaluation," Army R,D & A (Research, Development and Acquisition), September/October 1983, pp 26-28.

Goran, W.D., and W.D. Severinghaus, "Integrating Land Management and Training Through ITAM and GRASS," *The Military Engineer*, July-August 1991.

Goran, W.D., J. M. Westervelt, and H.E. Balbach, "Potential for Using Geographic Information Systems for Land Management Applications on Military Installations," *Agronomy Abstracts,* 1985 Annual Meetings of the American Society of Agronomy, December 1985, p 203.

Hayden, Timothy J., and David J. Tazik, "Integrated Natural Resource Monitoring on Army Lands and its Application to Conservation of Neotropical Birds," in Finch, D.M. and Peter Stangel, eds., *Status and Management of Neotropical Migratory Birds,* USDA Forest Service General Technical Report RM-229, July 1993. Report of a conference held 21-25 September 1992, Estes Park, CO, pp 258.

Describes the application of the Land Condition-Trend Analysis (LCTA) program to scores of military installations nationwide. Covers the overall LCTA approach to natural resources monitoring, and gives examples of its use for monitoring neotropical migratory birds.

Krzysik, A.J, *Ecological Assessment of the Effects of Army Training Activities on a Desert Ecosystem: National Training Center, Fort Irwin, California*, USACERL Technical Report N-85/13, June 1985. ADA159248.

Describes a study conducted at Fort Irwin, Cal., to assess the effects of large-scale Army training maneuvers and war game scenarios on the installation's desert ecosystem. Additional objectives of the study were to develop rigorous methodologies for quantifying environmental impact assessments, to describe species/ habitat associations, and to quantitatively summarize the relative relationship of experimental and control sites on the basis of vertebrate community structure.

Krzysik, Anthony J., Edwin E. Herricks, David J. Tazik, and Robert E. Szafoni, "A Primer of Successional Ecology," *Landscape Architecture* 71(4):482-487,510.

Lacey, R.M., and H. Balbach, *Evaluation of Areas for Off-Road Recreational Motorcycle Use Volume II: Alternate Soil Suitability Determination Methods*, USACERL Technical Report N-86, November 1980. ADA096528.

Volume II describes seven alternative methods for evaluating soil suitability for trailbike use, including simplified laboratory techniques.

Lacey, R.M., H. Balbach, S. Baran, and R.G. Graff, *Evaluation of Areas for Off-Road Recreational Motorcycle Use Volume I: Evaluation Method*, USACERL Technical Report N-86, November 1980. ADA096529

Volume I describes how to evaluate soil suitability of areas for off-road recreational motorcycle (trailbike) use on land under the jurisdiction of the Department of the Army.

Lacey, Robert M., and W.D. Severinghaus, *Application of the Recreation Opportunity Spectrum for Outdoor Recreation Planning on Army Installations*, USACERL Technical Report N-124, March 1982. ADA114892.

Describes the Recreation Opportunity Spectrum (ROS) and its current use in outdoor recreation planning and management. The ROS provides a framework for resources inventory, specification of recreational opportunities, resource capability and suitability analysis, selection of management objectives and practices, and impact assessment. The ROS concept can be used in Army recreation and land management planning.

Lacey, Robert M., D. McCormack, and D. Slusher, "Guide for Rating Soil Limitations for Off-Road Vehicle Trails," *National Soil Handbook, Part II* (U.S. Department of Agriculture, Soil Conservation Service, April 1979), Section 403.6 (D).

Lacey, Robert M., R.S. Baran, W.D. Severinghaus, and D.J. Hunt, *Evaluation of Areas for Recreational Snowmobile Use*, USACERL Technical Report N-105, May 1981. ADA101075.

Describes a recommended method to evaluate land areas on Army installations for use by recreational snowmobiles. The method includes recommended procedures to identify incompatible land uses, establish noise buffer zones, evaluate biological and terrain suitability, choose candidate areas or corridors, and establish trails. Factors considered in the evaluation method include user participation, existing trail systems, user demand, trail signing, vehicle operating conditions, and environmental assessment and monitoring.

Lozar, R.C., H. Balbach, and others. *Environmental Early Warning Systems (EEWS): Topic Area Brief Documentation*. USACERL Technical Report N-87/04, Jan 1987. ADA178515.

Describes each major area of concern ("Topic Areas") that provide user output via environmental impact demand equations in EEWS. The EEWS interactive computer system was designed to find potential environmentally-related problems associated with proposed changes in troop strength, mission, facilities, natural resource management, and land use.

Lozar, Robert C., "Global Climatic Change Management by Watershed Basin Units," Proceedings of the *XVII International Society of Photogrammetry and Remote Sensing*, Washington D.C., August 1992.

Messenger, Manette, et al., *Tracking Hazardous Materials through Army Installations*, USACERL Technical Report N-149, April 1983. ADA129103.

Investigates the feasibility of tracking hazardous material through procurement, distribution, use, collection, and disposal of U.S. Army fixed facilities. This is done to comply with government regulations of hazardous waste under the Resource Conservation and Recovery Act.

Messenger, Manette, R. Nichols, and R. Webster, *Description and Implementation of the Hazardous Materials Tracking System (TRACKER)*, USACERL Technical Report N-180, June 1984. ADA144107.

Outlines the features of a computerized tracking system that interfaces the Army installation procurement system with a database of known hazardous items to produce a monthly listing of the types and amounts of hazardous materials procured by each unit on post. This can be used to comply with current laws and Army Regulations 200-1 and 420-47.

Riggins, Robert E., "Base Support Technologies," *The Military Engineer*, No. 551, Aug 1992.

Riggins, Robert E., and E.D. Smith, *Aquatic Rational Threshold Value (RTV) Concepts for Army Environmental Impact Assessment*, USACERL Technical Report N-74, Jul 1979. ADA073032.

Presents the results of a study undertaken to develop practical techniques for evaluating the "significance" of predicted water quality impacts. The term "significant" is discussed, existing aquatic ecosystem models are reviewed, potential criteria for measuring significance are examined, and concept framework is presented. The result is an RTV concept for measuring the significance of impacts on aquatic features.

Schomer, P.D, A.J. Averbuch, and L.N. Lendrum, *Army Blast Noise Warning and Monitoring System*. USACERL Technical Report N-88/03, Feb 1988. ADA191230.

The purpose of this study was to develop the Noise warning and monitoring system (NWS) and to test its use, installation, operating and maintenance in typical Army environments. This system will alert the range control office when operational blast noise levels in a community exceed established levels, and will monitor the overall blast noise produced at an installation.

Schomer, Paul D., USACERL, "Activity Interference: Its Role in Noise Annoyance," *Symposium on Aircraft Noise Abatement Receiver Technology*, NATO/CCMS, 16-20 May 1994.

Schomer, Paul D., "A Model to Describe Community Response to Impulse Noise," *Noise Control Engineering Journal*, Vol. 18, No. 1, January/February 1982, pp 5-15.

Schomer, Paul D., "A Survey of Community Attitudes Towards Noise Near a General Aviation Airport," *J. Acoust. Soc. Am.*, Vol. 74, No. 6, Dec 1983, pp 1773-1781.

Schomer, Paul D., "Proposed New High-Energy Impulsive Sound Model," *Noise Control Engineering Journal*, Vol. 43, No. 5, Sep/Oct 1994, pp 179-191.

Severinghaus, W.D. "Guild-Based Land Management Model" in *Proceedings: Conference in Applications of the Guild Concept to Environmental Management*, W.D. Severinghaus and T.D. James, eds., USACERL Technical Manuscript N-86/07, Feb 1986. ADA167190.

Severinghaus, W.D., "The Need, Origin, and Theoretical Use of the Guild Theory, Introduction," in *Proceedings: Conference in Applications of the Guild Concept to Environmental Management,* W.D. Severinghaus and T.D. James, eds., USACERL Technical Manuscript N-86/07, Feb 1986. ADA167190.

Severinghaus, W.D., and R.R. Hinchman, "The Military and Natural Resource Conservation Value of Tactical Concealment Islands and Corridors," 1989, *Agron. Abstracts*, p 8.

Severinghaus, W.D., and T.D. James, eds., *Proceedings: Conference on Applications of the Guild Concept to Environmental Management*, USACERL Technical Manuscript N-86/07, February 1986. ADA167190.

Severinghaus, W.D., R.G. Goettel, and L.L. Radke, *Establishing Priorities for Acquiring Natural Resources Data Parameters*, USACERL Technical Report N-121, November 1981, 192 pp. ADA109720.

Explains procedures allowing personnel who manage natural resources at Army installations to gather and disseminate environmental data efficiently. The report defines data parameters required for natural resources management in the areas of (1) fish and wildlife; (2) forestry; (3) agricultural out leases; (4) outdoor recreation; (5) training and (6) buildings and grounds.

Tazik, David J., and Chester O. Martin, *U.S. Army Threatened and Endangered Species Research and Development Strategy and Action Plan*. USACERL Special Report EN-94/06, June 1994. ADA284207.

Tazik, David J., Victor Diersing, Jeffrey Courson, Steven D. Warren, R.B. Shaw, and Edward W. Novak, *A Climatic Basis for Planning Military Training Operations* *and Land Maintenance Activities*, USACERL Technical Report N-90/13, June 1990. ADA224174.

Trame, A., and D.J. Tazik, *The Implications of Ecosystem Management for Threatened and Endangered Species Conservation by the U.S. Army,* USACERL Technical Report 95/27, September 1995. ADA302406.

Designed for use by land managers and other policymakers. This report contains information on the background, definition, and land use implications of managing species via the ecosystem-wide approach as opposed to the single-species-at-a-time approach, which has been the norm.

Verner, J., R. Pastorok, J. O'Connor, W.D. Severinghaus, N. Glass, and B. Swindel, "Ecological Community Structure Analysis on the Formulation, Implementation, and Enforcement of Law and Policy," *The American Statistician*, 39(4, pt2):393-402, 1985.

Area 6: The Land Condition-Trend Analysis (LCTA) Process

The U.S. Army maintains records of personnel and equipment training on its installations. These records show dramatic increases in both numbers of troops and tactical vehicles using training areas. Additionally, modern weapons systems and combat scenarios place an ever-increasing demand on existing Army training lands. Until recently, however, the Army did not have standards for inventorying its training lands or for monitoring its natural resources. Without a standardized system, it is difficult to match training load with land capability and to develop any record of natural resource quality over time. Lacking such information, Army Major Commands and policy-makers cannot secure the necessary funding, personnel, and equipment needed to maintain the training lands in a stable, useful condition.

The Land Condition Trend Analysis (LCTA) program gives Army land managers a means to monitor the conditions of natural resources on their training lands. The primary objectives of LCTA are: (1) to assist evaluation of land capability to meet multiple use demands on a sustained basis, (2) to inventory conditions and monitor changes of natural resources, (3) to provide information for land management decisions, and (4) to implement a standard data collection, analysis, and reporting method enabling the compilation of data at an Army-wide level. The citations given in this chapter provide more information about these techniques and their application.

Data collected with LCTA includes topographic features, soil characteristics, botanical composition, vegetative cover, wildlife species, and surface disturbance. These data are collected from permanent plots whose locations are determined using a computer-based algorithm that uses a stratified-random design based on soils and land cover derived from satellite imagery. Thus, data collected on these plots are representative of the installation as a whole. The plot data can be used to estimate soil erosion, describe plant communities, estimate ground cover and disturbance, evaluate tactical concealment, and monitor land restoration projects. It can also be used to assess wildlife and endangered species habitat, determine forage condition, and verify data for input to geographic information systems.

LCTA provides Army land managers and administrators with long-term assessments of conditions and trends in vegetation and wildlife populations as well as estimates of soil erosion. The application of LCTA data can serve to: (1) assist with identification of under- and over-used training areas and therefor reduce the need for expensive land restoration programs, (2) help make subjective land management decisions, (3) serve as a basis of policy for use/non-use decisions, (4) help ensure the sustained availability and productivity of Army land, and (5) provide input for integrated natural resources management plans, environmental assessments, and environmental impact statements.

In 1987, the Assistant Secretary of the Army for Installations and Logistics reviewed the LCTA program and issued a statement calling for Army-wide implementation. Ongoing research to improve LCTA methods and develop and integrate applications is conducted by the Land Management Laboratory. Currently, LCTA is being implemented at over 50 installations representing Forces Command, Training and Doctrine Command, Army Materiel Command, U.S. Army Pacific, U.S. Army Europe, Army National Guard, the Marine Corps, and at the U.S. Military Academy. LCTA is one of the components of the Integrated Training Area Management Program.

6A: Applicable Results

Anderson, A.B., W.L. Sprouse, D.G. Kowalski, and P.J. Guertin. *LCTA Users Interface, Users Manual Version 1.0*, USACERL Technical Report 95/24, August 1995, ADA300797.

Anderson, A.B., W.L. Sprouse, D.G. Kowalski, and R.B. Brozka. *Land Condition-Trend Analysis Data Collection Software Users Manual: Version 1.0*, USACERL ADP Report 95/13, July 1995. ADA299981.

Describes the use of handheld field computers and customized LCTA data collection software. Details installation and use of data collection, database loading, and editing software. Gives minimum system requirements for running the programs.

Bagley, Calvin F., David G. Kowalski, and David J. Tazik, "Supervised Classification of SPOT Imagery Using LCTA Plant Community Data," Agronomy Abstracts, *Annual Meeting of the American Society of Agronomy*, (p.9), Oct. 1991.

Brozka, Robert J., Shaw, R.B., Balbach, H.E., and Diersing, V.E., "Natural Resources Management Using Land Condition Trend Analysis Information in Support of Military Training," *Agronomy Abstracts*, 1989 Annual Meetings of the American Society of Agronomy, October 1989, p 6.

Diersing, V.E., R.B. Shaw, and D.J. Tazik. 1992. "The U.S. Army Land Condition-Trend Analysis Program," *Environ. Manage.* 16(3):405-414.

Diersing, Victor E., Robert B. Shaw, and David J. Tazik, "The U.S. Army Land Condition-Trend Analysis Program: Methods and Implementation," *Annual Meeting of the Soil and Water Conservation Society*, Aug 91.

Hayden, Timothy J., and David J. Tazik, "Integrated Natural Resource Monitoring on Army Lands and its Application to Conservation of Neotropical Birds," in Finch, D.M. and Peter Stangel, eds., *Status and Management of Neotropical Migratory Birds*, USDA Forest Service General Technical Report RM-229, July 1993. Report of a conference held 21-25 September 1992, Estes Park, CO.

Describes the application of the Land Condition-Trend Analysis (LCTA) program to scores of military installations nationwide. Covers the overall LCTA approach to natural resources monitoring, and gives examples of its use for monitoring neotropical migratory birds.

Price, David, Alan Anderson, William Whitworth, and Patrick Guertin, *Land Condition Trend Analysis Data Summaries*, USACERL Technical Report 95/39, September 1995. ADA300753.

A general overview of LCTA data applications, documenting the potential use of the data in natural resource management plans and other conservation or compliance documents. Focuses on "first step" preliminary summarization of the univariate attributes of the vegetation and wildlife data collected on LCTA core plots. This is the first step in any data reduction and interpretation process. Necessary considerations required to properly interpret each summary are identidied in addition to the mathmatical calculations behind the analyses. A following report will examine more sophisticated and potentially informative, multivariate analyses.

Sprouse, W.L., and Alan Anderson, *Land Condition Trend Analysis (LCTA) Program Data Dictionary: Version 1.0*, USACERL ADP Report EN-95/03, April 1995, 229 pp. ADA295608.

Provides a complete description of each LCTA database entity and relationship, SQL commands to construct a new LCTA database, a database scheme diagram to help visualize the information structure, and SQL commands to migrate early versions of the database into the current structure.

Tazik, D.J., S.D. Warren, V.E. Diersing, R.B. Shaw, R.J. Brozka, C.F. Bagley, and W.R. Whitworth. *U.S. Army Land Condition-Trend Analysis (LCTA) Plot Inventory Field Methods*, USACERL Technical Report N-92/03, February 1992, 63 pp. ADA247931.

Outlines standard methods for collecting and maintaining a permanent LCTA database on the condition of Army land resources. LCTA uses standard methods to collect, analyze, and report natural resources data, and is the Army's standard for land inventory and monitoring. Included in the report are lists of equipment needed for data collection, and detailed procedures for establishing permanent field plots, collecting plant specimens, inventorying wildlife populations and maintaining the databases by periodic short- and long-term monitoring of the field plots.

6B: Underlying Research Information

Bern, C.M., 1993. Land Condition Trend Analysis Installation Report, Yuma Proving Ground, Arizona, 1991-1992. CEMML, Colorado State University, TPS 93-2.

Bern, C.M., 1994. Land Condition Trend Analysis Summary of Vegetation Monitoring, Pohakuloa Training Area, Hawaii, 1989-1993. CEMML, Colorado State University, TPS 94-3. 91 pp + app.

Block, P.R., 1994. Land Condition Trend Analysis at Fort Huachuca, Arizona, 1992-1993. CEMML, Colorado State University, TPS 94-2. 90 pp + app.

Bradshaw, S., and P.J. Thompson, *Options for Acquiring Elevation Data*. Jan 1989. USACERL ADP Report N-89/20. ADA220934.

Presents a short evaluative summary of the digital elevation products available from: (1) The Defense Mapping Agency, (2) The U.S. Geological Survey, and (3) private companies. Digital elevation data are crucial for GRASS applications that demand the ability to create useful, accurate, and current digital map layers.

Diersing, Victor E., David J. Tazik, and Edward W. Novak, 1987, *Growth Rate of Pinyon Pine (Pinus edulis) on Fort Carson and Pinon Canyon Maneuver Site, Colorado*, USACERL Technical Report N-87/20, June 1987. ADA183018.

Study of how long it takes for Pinyon Pine trees to grow to an adequate size to provide concealment for tracked vehicles. Age growth prediction equations were developed and the age structure of the current Pinyon Pine population was determined.

Diersing, Victor E., Robert B. Shaw, and David J. Tazik, "The U.S. Army Land Condition-Trend Analysis Program," *Environmental Management*, 16:405-414.

Area 7: Environmental Noise (Training-Related)

The U.S. Army Construction Engineering Research Laboratories has been engaged in military training noise research for more than 20 years and is a recognized world leader in the field. USACERL has developed a wide range of knowledge and tools that facilitate management of environmental noise pollution.

Noise pollution is a major consequence of military training. Worldwide, increasingly stringent noise legislation affects the design and peacetime use of military troop training procedures and facilities. In the United States no national noise regulations exist for environmental nonworkplace noise. Instead there is a hodgepodge of local and state noise regulations that are inconsistent and that usually do not properly account for military noise. Noise pollution typically receives attention as a result of political and legal action by annoyed citizens. The lack of national noise legislation means there is no legal benchmark for an acceptable noise level, and also that funding for noise problems often receives low priority in competition with issues that result in fines or violations of environmental laws.

Considerable noise and acoustics research is occurring in the world today, much of it aimed at reducing the noise output of commercial products such as office equipment and automobiles. Little of this research is directly applicable to military noise problems. The most significant sources of military noise are artillery, explosives, helicopters, and high performance low altitude jet aircraft. These devices produce noise that is very different in character from most environmental noise—such as that produced by traffic and manufacturing plants. Since the Army owns virtually all artillery and most of the helicopters, the Army bears the burden of performing the research and development required to deal with the resulting noise.

For most environmental pollution (air, water, solid waste), metric and dose limits are set by regulation; the primary research task is to develop mitigation methods. By contrast, the Army must determine how to meaningfully measure military noise. It must also develop procedures to assess the impact of military noise on humans and animals and to determine what environmental noise levels are safe and reasonable. Only after these issues are understood can meaningful noise management and mitigation procedures be developed and used.

Military noise sources require unique descriptive metrics because they are intense and transient and are rich in low-frequency energy. If the common A-weighted average sound level metric commonly used for industrial noise were used to measure noise from artillery, the resulting measured level would be very low, even for sounds that clearly seem very loud and annoying. Thus specialized metrics must be used, and annoyance response must be studied in terms of these metrics. USACERL has made significant contributions toward the selection and standardization of metrics appropriate for meaningful measurement of blast and helicopter noise.

Long-range propagation of noise from guns and helicopters is quite different from that of most other noise and requires unique calculation algorithms. Low-frequency acoustic energy—subject to little absorption by the atmosphere—can be heard at very long distances. Calculation of the propagation of blast noise through the atmosphere presents extreme computational challenges but is required to predict the noise level due to specific activities. Atmospheric conditions, particularly wind and temperature structure, have a profound effect on the noise level received at large distances.

Assessment and mitigation of military noise often requires an acoustic source model for each type of noise source; that is, for many different guns and aircraft. USACERL has developed such source models for a large number of Army weapons and equipment.

One useful technique for assessing the real-time effect of atmospheric conditions on long-range blast noise levels is to use field noise monitors, connected by telephone or radio link to range control. Until a few years ago, commercially available noise monitors could not perform the measurements required for meaningful measurement of blast noise. USACERL developed and fielded a true integrating noise monitor system at several installations that filled this need.

Noise level prediction is required for many planning and impact assessment tasks. The National Environmental Policy Act (NEPA) requires an Environmental Assessment or Environmental Impact Statement be prepared to assess impacts associated with new or changed activity; noise is often a primary issue. The Endangered Species Act requires assessment and mitigation of impacts on threatened and endangered species. Noise is often a factor in establishing suitable land use around military installations, codified in the noise level contours of the Environmental Noise Management Program.

USACERL has been a major contributor to the body of knowledge regarding the response of humans to blast noise. In addition to carrying out the research, USACERL has also been very active in disseminating research results for general use by means of participation in standards groups such as ANSI and ISO.

Until recently, virtually all impact assessment research was concerned with only one species, namely human beings. The effects of military noise on animals has become an area of concern comparatively recently, as a result of the Endangered Species Act. USACERL is engaged in determining dose-response relations for impacts of specific types of noise on specific species. In addition, major efforts are currently directed at developing methodology and technology for assessing noise impacts on animals.

The Army's most significant noise source is the blast noise created by large weapons. USACERL has developed tools such as BNOISE, SOUNDPROP, and BLASTMAP to predict blast noise problems in communities. BNOISE uses an empirical algorithm developed many years ago to provide characterization of long-term noise exposure in the form of noise exposure contours. USACERL has since made great progress in both blast sound propagation and understanding community response. SOUNDPROP enables accurate prediction of noise levels for specific situations. An improved version of BNOISE is currently under development to rectify many shortcomings. BLASTMAP enables noise management in real time by making physical predictions based on meteorological measurements and (where available) noise monitor measurements. No physical means to mitigate the noise of large weapons other than moving the firing points and impact areas or cessation of firing during unfavorable propagation conditions. These tools are designed to minimize cessation of firing while providing meaningful relief to the affected community.

The FIRE system is designed to develop and place noise assessment, management, and mitigation tools in the hands of the users and to link the various shareholders in noise assessment, management, and mitigation. It automates the generation of contours for the Environmental Office and Master Planning. Service groups can generate and check data remotely from their own offices. Noise complaint management is fully coordinated and automated. Noise monitors and BLASTMAP provide input to the Range Office. Planned improvements include "what if" gaming and noise minimization algorithms.

Helicopter noise is the Army's second most prevalent noise problem. USACERL has investigated methods of reducing community noise disturbance around airfields by determining how to use existing hangars as noise barriers and by exploring quieter landing procedures. USACERL has also gathered and analyzed noise emission data for several Army helicopters. These data are useful for assessing and predicting the noise impact of helicopter operations.

Small arms ranges are another source of community noise pollution. USACERL has developed several techniques for mitigating small arms noise, including proven methodology for designing effective noise barriers. Research to determine the effect of the ground surface on received noise level found that the type of ground surface can have a large effect on received noise level even at quite small distances from the guns. A computerized tool known as SARNEM (Small Arms Range Noise Evaluation Model) is currently under development that will enable assessment of the noise impact of small arms ranges. This effort would merge available data on sound propagation, weapons directivity, and community response into a small arms noise contouring capability.

7A: Applicable Results

Bass, Henry E., Richard Raspet, and John Messer, "Experimental determination of wind speed and direction using a three microphone array," *J. Acoust. Soc. Am.*, 97, 695-696 (1995).

Benson, L.J, M.J. White, K.J. Murphy, *Operational Noise Data for OH-58D Army Helicopters*. USACERL Technical Report, N-92/07, Jan 1992. ADA246822.

Gathered noise source emission data for the OH-58D helicopter. The data were normalized to 250 ft for use in noise maps. The data were also used to develop sound exposure level (SEL) versus distance curves for comparison with other helicopter data. This research is for use in the Installation Compatible Use Zone (ICUZ) program and for environmental assessments.

Fittipaldi, J.J., and S.D. Hottman, Installation Compatible Use Zone (ICUZ) Program," Environmental Impact Assessment Review, Vol. 7, No. 3, Sep 1987, 14 pp.

Fittipaldi, J.J., and S.E. Hottman, "A Microcomputer System for the Prediction of Blast Noise Impacts," *Noise Control Engineering Journal XXVI*, No. 3, May-June 1989, 12 pp.

Fittipaldi, J.J., *Procedures for Conducting Installation Compatible Use Zone (ICUZ) Studies*, USACERL Report N-88/19, Aug 1988. ADA200718.

Provides guidance to help Army installation environmental offices perform Installation Compatible Use Zone (ICUZ) studies. The purpose of the ICUZ Program is to protect the installation mission, as well as the public, by identifying noise-impacted areas so that concerned public local government, and installation elements can work together to minimize noise-sensitive development. The report describes in detail each step of the 12-step ICUZ study process, and information is given to answer those questions most asked by those who use ICUZ studies.

Hottman, S.D., J. Fittipaldi, R.G. Gauthier, and M.E. Cole, *MicroBNOISE: A User's Manual*, USACERL Technical Report N-86/12, June 1986. ADA173605.

Provides instruction for using Micro-BNOISE—a computer program that supports the Army's Installation Compatible Use Zone Program (ICUZ) by enabling installation personnel to examine the relative consequences of blast-related mission activities. Installation planners and managers can use this program to assess results of realigning and rescheduling mission activities.

Miller, G.S., R.E. Miller, L. Pater, and J.W. Shea, "Reduction of 5"/54 Gun Blast Overpressure by Means of an Aqueous Foam-filled Muzzle Device," NSWC TR 81-128, Dahlgren, VA, Aug 1981.

Noble, J.M., and M.J. White, "Incorporation of a large scale wind driven turbulence model into a range dependent parabolic equation," 120th meeting of the Acoustical Society of America, San Diego, CA (Nov 1990).

Pater, L., "Far Field Overpressure from TNT Explosions: A Survey of Available Models," NSWC TR 81-132, Dahlgren, VA, April 1981.

Pater, L., "An Investigation of Small-Arms Range Noise Mitigation: The Firing Shed and the Interlane Barrier," USACERL Technical Report EAC-92/01, Sep 1992. ADA258818.

Presents two experiments to evaluate the effectiveness of firing sheds and interlane barriers in reducing noise levels from small-arms ranges. Both experiments compare theoretical performance calculations to experimental data. Results showed that the firing shed achieved significant noise reduction to the rear, and that the interlane barrier achieved significant noise reduction in the far field.

Pater, L., and Raman Yousefi, "Hangars as Noise Barriers for Helicopter Noise," *Noise-Con 93 Proceedings: Noise Control In Aeroacoustics*, 2-5 May 1993.

Pater, L., Eric Sandeen, George Swenson, Jr., Kenneth McK. Eldred, Raman Yousefi and Walter Alvendia, *Comparison of Barriers and Partial Enclosures for Rifle Range Noise Reduction*, USACERL Technical Report EC-94/19, May 1994. ADA282799.

The noise from small arms firing may disturb surrounding sensitive land uses, especially residential areas. Use of complete enclosures (sheds) has been proposed as a better mitigation measure than simple barrier walls without a roof.

The results presented here indicate that sheds did not outperform simple barriers, probably since most of the muzzle blast is very directional. Design curves are included to assist in planning the height and location of the barrier.

Pater, L., "Incompressible Flow in a Radial Diffuser," M.S. Thesis, Arizona State University, 1969.

Pater, L., Raman Yousefi, and Walter Alvendia, *Noise Level Reduction of .50 Caliber Gun by Terrain Shielding*, USACERL Technical Report EC-94/25, July 1994. ADA284439.

Military training noise has the potential to generate complaints from surrounding communities. Barriers are often used to attenuate this noise at small arms ranges. Larger weapons are more difficult to mitigate. In this study, .50 caliber machine gun noise was effectively reduced by terrain barriers such as berms and ridges. A 3-m high berm reduced noise levels 5 to 10 dBA, and a 10-m high ridge resulted in reductions of 10 to 20+ dBA.

Peterson, S., and P. Schomer, *Acoustic Analysis of Small Arms Fire.* USACERL Technical Report, EC-94/06, Jan 1994. ADA278306.

Presents the results of a study of the spectral content of small arms fire at varying distances. These data can be used in the design of noise mitigating structures for small arms ranges. The one-third octave spectra of both the bow wave and muzzle blast, for distances ranging from 162 to 577 m from the source are presented. The data are then used to develop a model that predicts the relative levels of the two components over much larger distances.

Raspet, R., *Development and Description of a Computer Program for Predicting Impulse Noise Reduction by Barriers*, USACERL Technical Report N-87/10, March 1987. ADA179404.

Documents the development of the program, outlines barrier design considerations, and describes how to use the program. This will help the Army to estimate the amount of noise reduction provided by barriers from blasts, artillery, and gunfire.

Raspet, R., and Lewis Nelson, "Reduction of Artillery Noise by Natural Barriers," *Applied Acoustics* 19 (2), 117-130 (1986).

Raspet, R., M. Kief, and R. Daniels, "Prediction and Modeling of Helicopter Noise," USACERL Technical Report N-186, Aug 1984. ADA145764.

Sound exposure level (SEL) data from three Army helicopters were used to test a proposed method for calculating sideline decay developed for fixed-wing aircraft. The purpose of this report was to study if the same method could predict rotary-wing aircraft sideline decay with distance or if a more complex computer model is necessary. In addition, the sideline decay data were studied using variables known to affect sound attenuation. The purpose was to gain further insight into the mechanisms of sideline decay with distance.

Raspet, Richard, *Mitigation of Noise Impacts Via Operational Changes*, USACERL Technical Report N-76, Sep 1979. ADA074480.

Analyzes three case studies that can serve as a guide for using operational changes of artillery and demolition to reduce noise impacts at Army installations. In each study, the initial and final noise impact is documented by computer generated equal noise contours. The operational changes that produced the reduction or shift in contours are described and their impact estimated.

Schomer, P.D, A.J. Averbuch, and L.N. Lendrum, *Army Blast Noise Warning and Monitoring System*, USACERL Technical Report N-88/03, Feb 1988. ADA191230.

The purpose of this study was to develop the Noise warning and monitoring system (NWS) and to test its use, installation, operating and maintenance in typical Army environments. This system will alert the range control office when operational blast noise levels in a community exceed established levels, and will monitor the overall blast noise produced at an installation.

Schomer, P.D, A.J. Averbuch, R. Raspet, and R.K. Wolf, *Operational Noise Data From CH-47D and AH-64 Army Helicopters*. USACERL Technical Report N-88/04, Mar 1988. ADA191059.

The objectives of this study were to develop sound exposure levels (SEL) versus distance curves for flight operations and time-average sound level (LEQ) contours versus distance for static operations for two new Army aircraft. Sound levels produced by the helicopters were measured while hovering and traveling at various speeds in both heavily and lightly loaded configurations.

Schomer, P. D, L. Wagner, L. Benson, E. Buchta, K. Hirsch, and D. Krahe, *Evaluating the Degree of Annoyance Caused by Military Noise: Results of a Test Done at*

Munster, Federal Republic of Germany, USACERL Technical Report EC-94/04 March 1994. ADA283598.

Schomer, P., R. Raspet and A. Averbuch, *Operational Noise Data for US-60A and CH-47C Army Helicopters*, USACERL Technical Report N-131, June 1982. ADA118796.

The objectives of this study were to develop sound exposure level (SEL) versus distance curves for the UH-60A and CH-47C Army helicopters, to investigate the variation of SEL with aircraft speed, and to confirm the validity of the measurement procedures by comparing data obtained for UH-1H helicopters at Forts Campbell and Rucker. Sound levels produced by the helicopters were measured for heavily and lightly loaded aircraft which were hovering and traveling at various speeds and distances.

Schomer, Paul D., "A Survey of Community Attitudes Towards Noise Near a General Aviation Airport," *J. Acoust. Soc. Am.*, Vol. 74, No. 6, Dec 1983, pp 1773-1781.

Schomer, Paul D., "An Analysis of Community Complaints to Army Aircraft and Weapons Noise," *J. Acoust. Soc. Am.*, Vol. 73, No. 4, April 1983, pp 1229-1235.

Schomer, Paul D., "Assessment of Community Response to Impulsive Noise," *J. Acoust. Soc. Am.*, Vol. 77, No. 2, Feb 1985, pp 520-535.

Schomer, Paul D., "Decibel Annoyance Reduction of Low-Frequency blast Attenuating Windows," *J. Acoust. Soc. Am.*, Vol. 89, No. 4, April 1991, pp 1708-1731.

Schomer, Paul D., and L.R. Wagner, "Human and community response to military sounds: Results from field-laboratory tests of small arms, 25 mm cannon, helicopters and blast sounds," *Noise Control Engineering Journal*, Vol. 43, No. 1, Jan/Feb 1995, pp 1-14.

7B: Underlying Research Information

Bass, Henry E., Bruce A. Layton, Lee N. Bolen, and Richard Raspet, "Propagation of medium strength shock waves through the atmosphere," *J. Acoust. Soc. Am.* 82 (1), 306-310 (1987).

Bass, Henry E., Richard Raspet, and John Noble, "Influence of ground reflection on measurements involving band noise," *J. Acoust. Soc. Am.* 84 (6), 2275-2277 (1988).

Gilbert, K.E., and M.J. White, "The Parabolic Equation Applied to Outdoor Sound Propagation," *J. Acoust. Soc. Am.* 85:630-637 (1988).

Raspet, R., H.E. Bass, and Jean Ezell, "Effect of finite ground impedance on the propagation of acoustic pulses," *J. Acoust. Soc. Am.* 74 (1), 267-274 (1983).

Raspet, R., and S.K. Griffith, "The reduction of blast noise with aqueous foam," *J. Acoust. Soc. Am.* 74 (6), 1757-1763 (1983).

Raspet, Richard, and Michael T. Bobak, *Procedures for Estimating the Flat-Weighted Peak Level Produced by Surface and Buried Charges*, USACERL Technical Report N-88/07, Aug 1988. ADA199857.

This report contains procedures for environmental officers and planners to estimate the immediate noise impacts of demolition and explosive operations. It describes a three-step procedure that involves finding a peak level at a particular distance, based on data for TNT, and then calculating two correction factors, one for the type and weight of explosive and one for how deep the charge is buried. When the reference TNT level and these correction factors are combined, the sum is an estimate of the peak level which that charge will produce in that situation. This information can be used to predict the likelihood of complaints and damage, and procedures can be adjusted accordingly. This report gives tables to do this manually. A computer program has also been developed and installed on the Environmental Technical Information System (ETIS).

Raspet, Richard, and Wenliang Wu, "Calculation of average turbulence effects on sound propagation based on a Fast Field Program formulation," *J. Acoust. Soc. Am.* 97:147-153 (Jan 1995).

Raspet, Richard, Lixin Yao, Steven J. Franke, and Michael J. White, Comments on "The influence of wind and temperature gradients on sound propagation, calculated with the two way wave equations" [J. Acoust. Soc. Am. 87, 1987-1998 (1990)], *J. Acoust. Soc. Am.* 91 (1), 498-500 (1992).

Raspet, Richard, S.K. Griffiths, Joseph M. Powers, Herman Krier, Timothy J. Panczak, P. Barry Butler, and F. Jahani, *Attenuation of Blast Waves Using Foam* *and Other Materials*, USACERL Technical Report N-89/01, November 1988. ADA203148.

Documents several years of fundamental research into methods to quiet explosive noise and materials used to reduce the noise from explosions. The report reproduces in chronological order the USACERL research articles that have been published in different journals.

Schomer, Paul D., *Handbook of Acoustical Measurements and Noise Control, chapter 50. Community Noise Measurements*, John Wiley and Sons, Inc., 2nd Edition, New York, 1991.

Schomer, Paul D., High-Energy Impulsive Noise Assessment, *J. Acoust. Soc. Am.*, Vol.. 79, No. 1, Jan 1986, pp 182-186.

Schomer, P.D., and R. Raspet, *Acoustic Directivity Patterns for Army Weapons*, Supplement 2, USACERL Technical Report N-60, August 1984. ADA155219.

Describes tests conducted on 12 types of Army heavy weapons at Fort Sill, OK, and the development of precise sound-pressure level contours (directivity patterns) for Army weapons currently in use. The data obtained during these tests was also used to compile tables relating the charge weight to an equivalent weight of C-4 plastic explosives.

-Supp 1: *LAW and TOW antitank weapons and three routinely used weapon simulators.*

-Supp 2: *Abrams tank (M1-E1) 120-mm main gun.*

-Supp 3: *The Bradley Fighting Vehicle.* Report of tests done at Aberdeen Proving Ground, MD, on the M3 Cavalry Fighting Vehicle, CPT 406, and on several different guns and ammunition.

-Supp 4: *The Multiple Launch Rocket System.* Environmental noise emissions on Multiple Launch Rocket System weapons were measured in order to develop acoustic directivity patterns. Ignition and rocket engine noise were separated and measured in order to develop acoustic directivity patterns. Ignition and rocket engine noise were separated and measured; the vehicle track noise is similar to that of the Bradley Fighting Vehicle reported in Supp 3, and therefore not measured.

Schomer, P.D., R. Raspet, M. Wagner, D. Walker, D. Marshall, J. Brunner, *Methods for Detecting Low-frequency Signals in the Presence of Strong Winds*, USACERL Technical Report N-90/09, May 1990. ADA223980.

Describes two methods to better separate blast noise from wind-induced noise in unattended monitoring situations. One method is to use a windscreen, a device that prevents wind and wind-induced pressures from reaching the microphone diaphragm while allowing the unimpeded passage of true acoustical pressures to the microphone. The second method is to make the microphone-black box system "smarter" so that it can separate wind induced noise from true blast noise.

Sparrow, V.W., Modeling Nonlinear Acoustical Blast Waves Outdoors: a Research Summary. Sep 1991. USACERL Special Report N-91/24. ADA241030.

Summarizes research that developed and verified a numerical method to model nonlinear acoustical blast waves, and investigated the interaction between the finite amplitude blast waves and a natural ground surface. Absorbing boundary conditions were also developed to allow for a numerical solution on a relatively small computational domain. This modeling is necessary for very loud sounds (over 150 dB), where the mathematics governing the sound propagation become nonlinear.

Sparrow, V.W., *Finite Difference Numerical Model for the Propagation of Finite Amplitude Acoustical Blast Waves Outdoors over Hard and Porous Surfaces*, USACERL Technical Manuscript N-91/23, Sep 1991. ADA241795.

Describes a finite difference numerical model for the propagation of finite amplitude acoustic blast waves in a homogenous lossy atmosphere. The nonlinear air propagation equations included classical disipative effects and may easily be extended to include molecular relaxation effects. The model also accounts for both hard and simple porous media ground surfaces. A time-dependent locally reacting formulation of Morse and Ingard's phenomenological model of a porous medium has been developed to represent the porous ground.

Swenson, George W., Jr., Eric R. Sandeen, Larry L. Pater, and Hong C. Zhuang, *The Potential for Mitigation of Gun Blast Noise Through Sheltering of the Source*, USACERL Technical Report N-92/09, April 1992. ADA251884.

Shows the results of mathematical analyses for two idealized shelter models—one designed to mitigate artillery and tank blast noise, the other to mitigate rifle fire noise. These shelters are designed to shield the surrounding community from the disturbing low frequency noise components that are loud enough to violate local noise regulations and thereby risk the loss of training capacity.

White, M.J., and G.W. Swenson, Jr., "Effects of Wind and Temperature on Short-Range Sound Propagation: Solution by Fast Field Program," in *Developments in Mechanics, Volume 15: Proceedings of the Twenty-first Midwestern Mechanics Conference*, J.B. Ligon, H.W. Lord, M. Vable, V.W. Snyder, and G. Trevino, eds., pp 513-514, August 1989.

White, M.J., and K.E. Gilbert, "Application of the parabolic equation to the outdoor propagation of sound," *Applied Acoustics*, vol. 27, 227-238 (1989).

White, M.J, C.R. Shaffer, and R. Raspet, *Measurements of blast noise propagation over water at Aberdeen Proving Ground, MD*. Sep 1993, USACERL Interim Report EAC-93/02. ADA290383.

This study was part of a larger effort to systematically collect noise level and atmospheric data over a variety of terrains, coincident with Army-type explosions. This report provides blast data received over water, in a range of atmospheric conditions. Blast signals were processed to obtain peak-level, flat-weighted, and C-weighted sound exposure levels for each event and for each microphone in a nine-microphone array. Data collected will supplement existing blast noise data bases to provide a sufficient range of experimental conditions to test future blast noise propagation models.

White, Michael J., and Paul D. Schomer, "Lessons Learned in Operation Desert Thunderstorm", USACERL, *Symposium on Aircraft Noise Abatement receiver Technology*, NATO/CCMS, 16-20 May 1994.

Area 8: Threatened, Endangered, and Sensitive Species Issues

Presently, more than 950 species of plants and animals are protected under one of the most stringent environmental laws affecting Federal land—the Endangered Species Act (ESA). Over 120 Federally listed species, and 140 exclusively State-listed species are known or suspected to reside on Army lands. In many cases, these lands have been protected from extensive development and exploitation that has resulted in habitat fragmentation, ecosystem dysfunction, and population declines elsewhere. Protection given species under the Act, however, can constrain mission activities and impede land acquisition, thereby reducing defense readiness and jeopardizing lives. Furthermore, violations of ESA can result in lengthy and costly litigation that could lead to criminal and civil penalties and further constrain the mission. As the number of listed species increases, mission constraints and the management burden on military installations also increase. The Army's ability to address threatened and endangered species (TES) management requirements is limited because of inadequate information on: (1) the distribution, abundance, and status of TES on Army lands, (2) the effects of mission activities on TES and their individual or collective habitats within the ecosystem, and (3) mitigation and management options compatible with the mission.

USACERL has been involved in TES and related wildlife research since a publication by Severinghaus and co-workers in 1982. This publication, which lists listed species by installation, was followed in 1985 and 1991 with annotated directories of TES on Army lands (Diersing et al. 1985; Tazik et al. 1991). While useful in documenting known or suspected occurrences of TES on Army lands, keeping the appropriate information updated has remained problematic. Recent efforts have been directed at establishing a standardized database to track the status of TES Army-wide.

Two major research initiatives during the middle to late 1980s involved site-specific field work on the desert tortoise conducted by Krzysik at Fort Irwin (1994), and on the black-capped vireo conducted at Fort Hood (Tazik 1992, 1993), Camp Bullis (Shaw et al. 1989), and Fort Sill (Gryzbowski and Tazik 1993). These efforts have since expanded to desert tortoise research at 29 Palms Marine Corps Base, and to the golden-cheeked warbler and cave invertebrates at Fort Hood and Camp Bullis (currently unpublished). The experience gained through this work has proved extremely valuable in recent efforts to assist the Army in developing and assessing guidelines for management of the red-cockaded woodpecker on Army lands (Hayden and Carter 1994).

In 1993, the Army identified TES as the most important Army R&D requirement. Specifically, the Army natural resources community is concerned with evaluating impacts of military operations on TES, establishing objective and scientifically sound protocols for inventory and monitoring TES on military lands, and developing practical and effective mitigation and management strategies. A U.S. Army TES R&D strategy was developed subsequently as a mechanism to address these priority requirements (Tazik and Martin 1994).

USACERL's current research efforts emphasize ecosystem and community-based approach approaches to TES management (Trame and Tazik 1995, Martin et al. 1995), and focus on impact and risk assessment (Getz et al. 1995). Additional attention is being given to matters involving interagency coordination and cooperation (Tazik et al. 1994). Results of this on-going research will be made available as it is completed.

8A: Applicable Results

Carter, J.H., and T.J. Hayden, *Biological Assessment of Army-Wide Management Guidelines for the Red-cockaded Woodpecker*, USACERL Special Report EN-94/03, Feb 1994, 54pp+19.

This document was prepared to meet the requirements of the Endangered Species Act. It examines briefly the effects that the implementation of the proposed management guidelines for the Red-cockaded Woodpecker (RCW) would be expected to have on the RCW and other associated threatened and endangered species at each Army installation where the RCW is (or was) found. The conclusion is that use of the guidelines would stabilize existing populations in most cases. Some exceptions were noted where preexisting non-Army issues and constraints affected populations.

Grzybowski, Joseph A. and David J. Tazik, *Status and Management of the Black-capped Vireo on Fort Sill, Oklahoma, 1988-1991*, USACERL Technical Report EN-93/06, Mar 1993. ADA269217.

Details the distribution, abundance, dispersal, minimum survival, habitat requirements and reproductive success on vireos on Fort Sill, OK. Recommends ways to help protect the black-capped vireo, which is on the Federal list of

endangered species , and lives on the Fort Sill Military Reservation, and military installations in Texas.

Hayden, T.J., *Environmental Assessment of Army-Wide Management Guidelines for the Red-cockaded Woodpecker*, USACERL Special Report EN-94/04, Jan 1994, 37pp+61.

This programmatic assessment was prepared to meet requirements of the National Environmental Policy Act. It examines, in a programmatic and non site-specific manner, the environmental and socioeconomic consequences of the proposed implementation of Army-wide management guidelines for the Red-cockaded Woodpecker. Each affected installation is proposed to prepare a site-specific management plan, using the principles contained in this environmental assessment as guidance.

Hayden, Timothy J., and David J. Tazik, "Integrated Natural Resource Monitoring on Army Lands and its Application to Conservation of Neotropical Birds," in Finch, D.M., and Peter Stangel, eds., *Status and Management of Neotropical Migratory Birds*, USDA Forest Service General Technical Report RM-229, July 1993. Report of a conference held 21-25 September 1992, Estes Park, CO.

Describes the application of the Land Condition-Trend Analysis (LCTA) program to scores of military installations nationwide. Covers the overall LCTA approach to natural resources monitoring, and gives examples of its use for monitoring neotropical migratory birds.

Krzysik, A.J., *The Desert Tortoise at Fort Irwin, California: a Federal Threatened Species*. USACERL Technical Report EN-94/10, September 1994. ADA 299969.

Krzysik, A.J., *The Mohave Ground Squirrel at Fort Irwin, California: a State Threatened Species*. USACERL Technical Report EN-94/09, September 1994. ADA299946.

Severinghaus, W.D., ed., *Proceedings: NATO CCMS Seminar Blue Book 159, Preservation of Flora and Fauna in Military Training Areas*, Conference Proceedings N-87/09, January, 1987. ADA179754.

Severinghaus, W.D., H. Balbach and L.L. Radke, "Endangered Species on U.S. Army Installations," USACERL Technical Report N-134, August 1982. ADA119546.

Supplies two lists: one identifies endangered species by installation, and the other identifies the installations by endangered species. The use of these two lists will help the Army major commands and installations organize environmental surveys and communicate to solve endangered species management problems before possible mission impairment.

Shaw, Robert B., Richard D. Laven, and David J. Tazik, "Mitigation Measures for Endangered Species on the Pohakuloa Training Area, Hawaii", Annual Meeting of the American Society of Agronomy, San Antonio, Texas (Abstract on page 11), Oct 1990.

Tazik, D.J., and C.O. Martin; *U.S. Army Threatened and Endangered Species Research and Development Strategy and Action Plan*. USACERL Special Report EN-94/06, Jun 1994. ADA284207.

Defines the Army's approach and framework for planning, execution, and transfer of research necessary to deal effectively with challenges to TES on Army lands. The strategy establishes the process, approach, and focus the Army research and development community will use to develop cost effective products and capabilities to meet requirement under the Endangered Species Act and applicable Army regulations. It also ensures efficient allocation of R&D resources, appropriate levels of interservice and interagency coordination, and timely transfer of useful research products to the field.

Tazik, David J., John D. Cornelius, and Cynthia A. Abrahamson, *Status of the Black-capped Vireo on Fort Hood, Texas, Volume I: Distribution and Abundance*, USACERL Technical Report EN-94/01, vI, Nov 1993. ADA275757.

Reports the results of a 3-year ecological status survey (1987-89) of the black-capped vireo, an endangered species that resides at Fort Hood, Texas. This was done as part of the effort to fully comply with the Endangered Species Act.

Tazik, D.J., J.A. Grzybowski, and J.D. Cornelius, *Status of the Black-capped Vireo on Fort Hood, Texas, Volume II: Habitat*, USACERL Technical Report EN-94/01, vII, Nov 1993. ADA275677.

Tazik, D.J., J.D. Cornelius, *Status of the Black-capped Vireo on Fort Hood, Texas, Volume III: Population and Nesting Ecology*, USACERL Technical Report EN-94/01, vIII, Nov 1993. ADA277544.

8B: Underlying Research Information

Krzysik, A.J., *Biodiversity and the Threatened / Endangered / Sensitive Species of Fort Irwin, CA.* USACERL Technical Report EN-94/07, Sep 1994. ADA291289.

Describes the biological and geophysical characteristics and environment of Fort Irwin, describes the Army training missions at the Army's National Training Center and summarizes the effects of the military training mission at Fort Irwin on woody vegetation and the vertebrate fauna. A detailed assessment of the current status of threatened, endangered, and sensitive animals and plant is also given. Priorities for environmental management, mitigation, research, and monitoring at Fort Irwin are discussed.

Krzysik, A.J., and A.P. Woodman. 1991. *Six years of Army training activities and the desert tortoise.* The Desert Tortoise Council, Proceedings of 1987-1991 Symposia 1991: 337-368.

Krzysik, A.J., E.E. Herricks, D.J. Tazik, and R.E. Szafoni. 1981. "A primer of successional ecology," *Landscape Architecture* 71:482-487, 510.

Laven, R.D., R.B. Shaw, P.P. Douglas, and V.E. Diersing. 1991. Population structure of the recently rediscovered Hawaiian shrub Tetramolopium arenarium ssp. arenarium var. arenarium (Asteraceae). *Ann. Mo. Bot. Gard.* 78:1073-1080.

Tazik, D.J., C. Martin, P. Pierce, and J. Ruth, *Proceedings - Interagency Endangered Species Symposium.* USACERL Special Report EN-94/08, Aug 1994. ADA286346.

These proceedings are the product of a symposium held 26 and 28 April 1994 in Washington, DC. Representatives from invited agencies presented papers addressing the following topics: agency mission, jurisdiction, information needs, process, issues of interest, current agency activities, information gaps/problems, and products/results. Findings and recommendations were generated through facilitated discussions during the second day of the symposium.

Tazik, David J., and John D. Cornelius, *The Black-capped Vireo on Fort Hood, Texas, Vol III: Population and Nesting Ecology,* USACERL Technical Report EN-94/01, Nov 1993. ADA277544.

Reports the results of a 3-year ecological status survey (1987-89) of the black-capped vireo, an endangered species that resides at Fort Hood, Texas. This was done as part of the effort to fully comply with the Endangered Species Act. Also, *Volume I: Distribution and Abundance* (ADA275757), *Volume II: Habitat* (ADA275677).

Tazik, David J., Dennis M. Herbert, John D. Cornelius, Timothy Hayden, and Billy Ray Jones, *Biological Assessment of the Impact of Military-Related Activities on Threatened and Endangered Species at Fort Hood, Texas*, USACERL Special Report EN-93/01, Dec 1992. ADA263489.

Looks at how Army military activities at Fort Hood, including maneuver, live fire, aviation training, and operational testing, may affect five Federally endangered species known to occur on Fort Hood. The black-capped vireo and the golden-cheeked warbler are of primary concern.

Tazik, David J., Renee A. Sherman, and Jeffrey A. Courson, *Annotated Directory of Threatened and Endangered Wildlife Species on Selected U.S. Army Installations East of the Mississippi River*, USACERL Technical Report N-91/26, May 1991. ADA238394.

Summarizes available information on the known or potential occurrence of Federal and state listed threatened and endangered species on major Army installations east of the Mississippi.

Trame, A., and D.J. Tazik, *The Implications of Ecosystem Management for Threatened and Endangered Species Conservation by the U.S. Army,* USACERL Technical Report 95/27, September 1995. ADA302406.

Designed for use by land managers and other policymakers. Contains information on the background, definition, and land use implications of managing species via the ecosystem-wide approach as opposed to the single-species-at-a-time approach which has been the norm.

Area 9: Cultural Resources

The importance of the country's cultural heritage was established in the 1960's, well before the implementation of the National Environmental Policy Act (NEPA). In practice, the requirements of the National Historic Preservation Act (NHPA) have worked in parallel with those of NEPA. The Army recognized that cultural resources issues were becoming more important in the 1970's, when proactive field surveys became required before implementation of construction projects and certain other land uses. Several questions emerged; among them "What action should we take when artifacts are located?" "What should we do with the artifacts recovered?" and "What restrictions on our planned uses follows discovery of an historic site?" Considerable work focusing on these, and other, questions was initiated at USACERL and at the U.S. Army Engineer Waterways Experiment Station (CEWES), Vicksburg, MS. While efforts at CEWES concentrated on the needs of the 400+ water resources projects, and those at USACERL on military installations, a majority of the principles and procedures are easily transferrable.

Cultural resources research began at USACERL in 1986 with two projects directed at solving problems in cultural resources information management. The first effort involved the establishment of a bulletin board, the Cultural Resources Information Bulletin Board (CRIBB), to facilitate the exchange of information between cultural resource managers on military installations, establish a forum to discuss Cultural Resources Management (CRM) issues, and provide updates on current legislation. This project was followed by the development of a database management system for cultural resources, the Cultural Resources Information System (CRIS), which provides installation personnel with easy-to-use, predesigned CRM database structures in a run-time, MS DOS based, database management system. CRIS has been distributed upon request to over 200 installations. These initial projects resulted in the collection of information on the status of cultural resources compliance on military installations. It was apparent that many installations lacked cultural resource management professionals to manage the compliance process. Much of the training and testing land operated by DOD had not been surveyed for cultural resources and the extent of impacts to these resources was not well understood. This realization has directed much of the cultural resources research performed by the Cultural Resources Research Center (CRRC).

The next significant effort in cultural resources research at USACERL began in 1988 with the development of a Historic Properties Management Plan (HPMP) for the U.S. Military Academy, West Point. This project involved the development of an archeological predictive model employing geospatial data developed in the geographical information system (GIS), GRASS, developed at USACERL. The HPMP was developed in digital format combining the geospatial data with associated records and standard operating procedures accessible through a desktop computer. The CRRC's incorporation of new technologies, in this case GIS and integrated computer environments, to the problem of cultural resource management, began with this project and has remained a major focus of USACERL's cultural resources research program. The use of site prediction models as decision support management tools for planning and assessing the potential impacts of proposed land use actions has led to the development of an integrated cultural resources decision support system (XCRIS), which is currently fielded at four military installations. The initial work on this project was funded by the DOD Legacy Resources Management Program to provide a new generation of decision support tools for installation land managers. XCRIS integrates GIS with relational databases (DBMS) and multimedia capabilities under a custom built graphical user interface (GUI) designed around the cultural resource management process. The GUI was developed to be easily modified for customization to the particular needs of the land manager. It is targeted towards the novice GIS and DBMS user and addresses the problem of personnel turnover and loss of GIS expertise on installations. The easy-to-use, "pull down" menu-driven system significantly reduces the learning curve required to use standard, line command driven, GIS and DBMS software. Within hours, novice users can quickly assess the potential impacts of proposed land use actions and produce a series of alternative scenarios accompanied by reports and maps.

In 1991, cultural resource professionals at USACERL were established as the Cultural Resources Team in the Environmental Division of the laboratory. The original group was comprised of three archeologists and two historic architects. Since 1991, the team has been established as the Cultural Resources Research Center (CRRC) and has grown to 14 cultural resources professionals covering the wide spectrum of cultural resources issues encountered on military installations and training lands. These include: identification and evaluation of historic building, structures and landscales; geoarcheological process modeling; archeological predictive modeling; geophysical prospecting; archeological applications in remote sensing; development of regional and national historic themes and contexts; Native American consultation; and problems in curation of artifacts and historic documents.

The CRRC's current emphasis is on two related problems: cultural resource discovery and assessment. These efforts are targeted towards cost-effective methods and tools for the discovery of archeological sites through the application of new and emerging technologies, and the eligibility assessment of these resources using reliable, yet cost-effective approaches.

Many universities have been significantly involved in CRRC's research program. The location of USACERL near the campus of the University of Illinois has resulted in a close working relationship between the two organizations. Much of CRRC's research is accomplished through collaborative efforts between USACERL principal investigators and University of Illinois faculty and graduate students. The CRRC has worked closely with the University of Arkansas' Center for Advanced Spatial Technologies and the Arkansas Archeological Survey which is co-located with the University. The CRRC is also working on basic research and development projects with the Army Research Office, the Department of Geography, University of Kansas, and the Department of Civil and Environmental Engineering at the Massachusetts Institute of Technology. Collaborative efforts between universities and the CRRC is the cornerstone of its research program.

9A: Applicable Results

Albertson, P.E., D. Meinert, and G. Butler, *Geomorphic Evaluation of Fort Leonard Wood*, CEWES Technical Report GL-95-19, October 1995. 105 pp + app.

This interagency study of Fort Leonard Wood, MO was initiated under DOD's Legacy Resource Management Program. It had the objective of providing information necessary for compliance with the NHPA regulations for identification of archeological sites, while also providing a baseline against which many installation activities could be compared in the future. Four appendices contain project data on soils, carbon dating, and palynology findings.

Briuer, F.L., ed, *Proceedings of a Corps of Engineers Symposium on Automation Tools and Database Development for Cultural Resource Managers: 17 April 1990, Las Vegas, NV*, CEWES Technical Report EL-92-11, January 1992. 96 pp.

Compilation of nine technical papers presented at a symposium for Corps of Engineers personnel on 17 April 1990. As suggested by the title, application of computer-assisted technologies is emphasized.

Ellis, G.L., C. Lintz, W.N. Trierweiler, and J.M. Jackson, *Significance Standards for Prehistoric Cultural Resources: A Case Study From Fort Hood, Texas*, USACERL Technical Report CRC-94/04, August 1994. ADA288702.

Any cultural resources management (CRM) program needs standards to determine which sites merit protection under the NHPA. This study suggests that a research design be prepared which is specific to the needs of the area proposed to be surveyed. Through knowledge of the important questions whose answers are not known, a better survey design and reasonable standards may be developed to meet realistic needs. In the Fort Hood case study, the actual history of the development of a CRM program is presented. It is suggested that this may serve, in many cases, as a model for CRM programs at other, major Federal installations with similar needs and problems.

Frison, George, Dennis Toom, M.L Gregg, David Schwab, Robert Mainfort, James Walker, L.L. Scheiber, George Gill, and John Wiliams, *Human Adaptations in the Northern Great Plains*, A volume in the Central and Northern Plains Archeological Overview, USACERL Special Report, in press.

Collectively, the entries in this study provide the required archeological overview for the Northern Great Plains. It fits into a multi-volume series which is intended to cover the central and northern Great Plains. Cultural resources managers and consultants may use this information in lieu of developing separate studies of significance against which individual surveys may be examined.

Grosser, Roger D., *Historic Property Protection and Preservation as US Army Corps of Engineers Projects*, CEWES Technical Report EL-91-11, 63 pp, August 1991.

Handbook prepared to assist designated historic property managers at Corps project sites. Provides guidance on required records and reports. Discussion of coordination requirements and relevant legislation and rules is equally applicable to any land manager.

Hofman, Jack L., 1996, *The Archeology and Paleoecology of the Central Great Plains*, a volume in the Central and Northern Great Plains Archeological Overview, USACERL Special Report, in press.

Provides background materials and presents data on the archeology and paleoecology of this large area. May be used for the overview in interpreting the significance of findings from site studies within this area without necessity of separate research.

Mann, Diane K., M. Higgins, and L. Mikulich, *User's Guide for Cultural Resources Information Bulletin Board (CRIBB)*, USACERL Technical Report N-88/02, October 1987. ADA188727.

The CRIBB system was placed on the existing Environmental Technical Information Systems (ETIS) bulletin board, and was available by toll-free dialup to all installation cultural resources managers. A wide variety of issues was discussed in the many thousands of postings made by those managers. The ETIS has been superseded several times, most recently by the (DoD-wide) Defense ENvironmental Information EXchange (DENIX).

Mathewson, C.C., T. Gonzalez, and J.S. Eblen, *Burial as a Method of Archeological Site Protection*, CEWES Technical Report EL-92-1, 125 pp, January 1992. ADA247685.

The issue of protection of archeological sites may be a difficult one for a land manager. It is often suggested that reburying the site may be a relatively easy way to preserve it at low cost. The research presented here was carried out by Texas A&M University, and examined the chemical and physical changes related to long burial times. Artificial study sites were created and subjected to stresses, including compression by tracked vehicles. More study was recommended before guidance could be developed for use.

Nickens, Paul, ed., *Perspectives on Archeological Site Protection and Preservation*, CEWES Technical Report EL-91-6, 150 pp, June 1991. ADA238293.

Collection of 14 papers presented at two symposia devoted to field preservation of archeological sites. Representatives from Federal and state agencies, university faculty, and private practitioners are represented.

Nickens, Paul R., *Use of Signs as a Protective Measure for Cultural Resource Sites*, CEWES Technical Report EL-93-6, April 1993, 95pp + app, ADA267263.

Understanding, let alone managing, human behavior is a complex issue for everyone. Land managers often must determine the best ways to minimize or eliminate vandalism and theft directed at known or suspected archeological sites and other historic properties. The nature and magnitude of the problem are briefly examined, and a longer presentation is made of possible motives and approaches relating to each of them. Examples are given of signs which are designed to redirect different behaviors, with their relative effectiveness reported for each. Appendix C shows 44 signs used by different agencies for this general purpose.

Rush, Laurie, *Design and Test of Prototype Curation Facilities at Fort Drum, New York*, USACERL Technical Report CRC-94/05, September 1994. ADA288473.

Federal regulations require that artifacts and other historic materials be professionally held and interpreted. Further, standards for storage of these materials require building specialized structures to hold the items and their associated documentation. This is not a traditional Army tasking, and no existing facility plans or standards existed for this purpose. In this case study, Fort Drum's needs were evaluated, and guidance was developed to convert an existing structure to an adequate curation facility. In general, the standards developed may be used by most military installations and many other agencies.

Thorne, Robert M., *Guidelines for the Organization of Archeological Site Stabilization Projects: A modeled Approach*, U.S. Army Waterways Experiment Station Technical Report EL-88-8, 46pp + app, June 1988. ADA196661.

Established guidelines for planned future research into site stabilization techniques and relative effectiveness of those approaches. Describes the processes planned to be used for evaluation.

Westervelt, J.D., and Goran, W.D., 1984, Predictive Models for Historic/Prehistoric Site Locations with a Geographic Information System, 76th Annual Meeting of the American Society of Agronomy, Las Vegas, NV, November, 1984.

Wood, Raymond, M.J. O'Brien, K.A. Murray, and J.C.Rose, 1995, *Holocene Human Adaptations in the Missouri Prairie-Timberlands.* A volume in the Central and Northern Plains Archeologacal Overview, USACERL Special Report 95/29, August 1995, 218 pp.

Collectively, the entries in this study provide the required archeological overview for the state of Missouri north and east of the Ozark Mountains. It fits into a multi-volume series, which is intended to cover the central and northern Great Plains. Cultural resources managers and consultants may use this information in lieu of developing separate studies of significance against which individual surveys may be examined.

Zeidler, J.A., 1995, *Archaeological Inventory Survey Standards and Cost-Estimation Guidelines for the Department of Defense*. USACERL Tri-Services CRRC Special Report 96/40, December 1995.

9B: Underlying Research Information

Wisseman, S.U., J. Isaacson, W.S. Williams, T.J. Riley, J.J. Fittipaldi, D.K. Mann, and P.K. Hopke, *Analytical Techniques in Archaeological Research*, USACERL Technical Report N-88/24, 106pp, September 1988. ADA202084.

Essentially a catalog or reference guide to the archeometric techniques commonly used for study of archeological sites. Techniques are defined and described, and equipment is described and sources given for procurement.

Mann, DK, M. Messenger, R.D. Webster, D.P. Gerdes, M.E. Higgins, 1986, *The DEEP Knowledge-Based System*, USACERL TR N-86/09, March 1986. ADA166863.

User guide for the DEEP Knowledge-Based System, a program to allow Army environmental personnel an easy way to share problems, ideas, solutions, and information on the latest proven technologies.

Zeidler, J.A., 1982, Pothunting and vandalism of archaeological sites: an Ecuadorian example. In *Rescue Archaeology: Papers Presented at the First New World Conference on Rescue Archaeology*. R. L. Wilson and G. Loyola, editors. pp.49-58. Washington, DC: The Preservation Press.

Zeidler, J.A., and P. Stahl, 1990, Differential bone-refuse accumulation in food-preparation and traffic areas on an early Ecuadorian house floor. *Latin American Antiquity* 1(2):150-169.

Area 10: Environmental Impact Assessment

The need for better techniques to assess the environmental consequences of Army actions was the origin of land management-related environmental research at USACERL in 1971. In a sense, each other area of environmental focus was an extension of this original approach. Only the noise program, initiated at approximately the same time, shares this longevity of approach. Several computer-based systems have been developed over the years to assist the Army and DOD to better handle the questions arising from the potential for Army activities to result in adverse environmental effects. The National Environmental Policy Act (PL 91-190) (NEPA) marks the legislative basis for this concern, and a majority of the products developed between 1971 and 1985 were directly related to achieving better response to the NEPA guidelines and regulations.

The Environmental Impact Computer System (EICS) was the first product. Conceptually, this system involved an extremely large, multi-layered matrix, with possible Army activities on one axis and attributes of the environment on the other. At each intersection was nested a set of possible responses relating to the effect of that activity on that attribute in different circumstances. Through application of screening questions to develop a feeling for the environmental setting, literally millions of variations in predicted "need to consider" were available. Use of the system was best made on very large projects where weeks and months were available to plan the approach to preparation of the assessment. In later years, it has been applied to the scoping process introduced through the 1978 NEPA Regulations (40 CFR 1500-1508). The Economic Impact Forecast System (EIFS), the Computer-aided Legislative Data System (CELDS), and other systems not examined here were also developed to aid the NEPA process in its first decade.

At the request of various Army agencies and executives, NEPA documents, Environmental Assessments (EAs) and Environmental Impact Statements (EISs), were occasionally prepared by the staff of USACERL. Those that exhibit characteristics potentially useful to land managers and students of environmental assessment are cited below. In general, these are situations where some critical element of the proposed action required special, inside the Army, knowledge, or where multiple converging issues resulted in actions that could not be properly defined in time for contracting efforts. In the process of preparing these documents, new research tools were often applied before their official release, and the important lessons learned were applied to the final release.

10A: Applicable Results

Balbach, H.E., D.L. Price, W.R. Whitworth, M.K. Chawla, and E.R. Schreiber. *Final Environmental Impact Statement. 1995. Military Training Use of National Forest Lands Camp Shelby, Mississippi.* Department of Army, National Guard Bureau and Mississippi Army National Guard. USACERL Special Report 95/10, June 1995. ADA295360.

This report is the first EIS to be required by the Forest Service for a military training special use permit for national forest lands. It examined many different locations and magnitudes of possible continuation of National Guard training at Camp Shelby, MS. Extensive application was made of of LCTA, ITAM, and other USACERL products cited elsewhere in this bibliography. More than 2,200 public and agency comments were received on the Draft EIS, and each is answered individually.

Balbach, Harold E. *Final Environmental Impact Statement - Blackbird Control on Two Army Installations*, USACERL, January 1975, 245 pp.

Assessment of a problem deemed critical by the Army. Millions of blackbirds established a winter roost adjacent to family housing areas at Fort Campbell, KY/TN as well as at Milan AAP, TN. It was proposed to treat the roosts at night with a detergent spray in the belief that loss of body heat would reduce bird populations. Prepared under special emergency EIS rules, the Draft was prepared in 12 days and the Final EIS in 30 days. A supplement (see Area 10B) was prepared to address late public comments, and the courts allowed the action to be performed.

Balbach, Harold E., T.A. Lewis, L.V. Urban, and R.K. Jain, *Environmental Impact Assessment Study for Army Military Programs*, USACERL Technical Report D-13, USACERL, December 1973. AD771062.

Describes, and gives examples of a proposed plan to evaluate all Army military activities in matrix format. In this proposed matrix, 2,000 activities are divided into nine "functional areas" (construction is one such area), and compared with the environmental attributes of 12 "technical specialties," such as ecology or water quality.

Lozar, R.C., and H. Balbach, *The Environmental Early Warning System (EEWS): Concept Description*, USACERL Technical Report N-144, January 1983. ADA122356.

Shows a concept description of EEWS: an interactive computer system designed to give the Department of the Army Headquarters and Major Command planning and decision-making personnel a way to quickly find potential environment-related problems associated with proposed changes in troop strength, mission, facilities, natural resource management, and land use. Included are a system description from the user's point of view, a brief explanation of how the system calculates results, and descriptions of the system's tabular and location-specific data handling capabilities.

Riggins, Robert E., and J.C. Kaden, *Training Impact Prediction System Users Manual*, USACERL Interim Report N-85/12, May 1985. ADA158600.

Describes the use and implementation of the Training Impact Prediction System — an interactive, user-friendly, computer-based system Army planners and land managers can use to predict environmental impacts on Army Training lands. The system is accessed through the Environmental Technical Information System.

Tyler, E.H., W. Wheeler, and C. Lau, *Integration of Environmental Planning Into the Army Master Planning Process*, USACERL Technical Report EC-93/01, October 1992. ADA262586.

Examines integration of environmental planning into the Army installation master planning process within the AR 210-20 series. Suggests that short-term crises may be minimized through comprehensive assessment of master plans at the programmatic level, with followon tiering of more specific actions. Automated tools and techniques which may be of use in this process are reviewed.

10B: Underlying Research Information

Balbach, Harold E., et al., *Supplement to Final Environmental Impact Statement - Blackbird Control at Two Army Installations*, USACERL, August 1975, 168 pp.

The action to manage blackbird populations was proposed in late 1974, and a Draft EIS was filed in late December, followed by an "emergency" Final EIS in January. The courts required, however, that the public comments received on the FEIS be answered in a supplement, even though the action was allowed to proceed. This supplement, then, is a followup to the FEIS, and contains the response to comments which would have been normal in a FEIS not processed under emergency criteria.

Huppertz, C.E., K.M. Bloomquist, and J.M. Barbehenn, *EIFS 5.0, Economic Impact Forecast System, User's Reference Manual*, USACERL Technical Report TA-94/03, July 1994. ADA288880.

The EIFS was originally developed by USACERL to assist military installation planners and preparers of NEPA documentation to determine, in a standardized and objective manner, the economic and social effects potentially associated with an Army action or project.

Jain, R., E. Novak, H.E. Balbach, and J.J. Fittipaldi, *Environmental Impact Computer System Attribute Descriptor Package Reference Document,* USACERL Technical Report E-86, April 1976. ADA024303.

Names, defines, and suggests the relevance to Army actions of more than 700 "attributes," or characteristics, of the biophysical and socioeconomic environment. Each attribute was used in separate studies that predicted the "need to consider" them when more than 2,000 different possible Army activities were performed.

Belles, R.C., M.S. Larson, and R.C. Lozar, *Environmental Early Warning Systems (EEWS): Data Input Manual,* USACERL Technical Report N-87/03, Jan 1987. ADA178254.

Describes the methods for entering information to the EEWS database, gives examples of manual input by a data-loading specialist, and describes automated loading procedures by a systems maintainer. EEWS is an interactive computer system designed to give planners and decision makers a way to quickly find potential environmental related problems associated with proposed changes in troop strength, mission, facilities, natural resource management, and land use.

Fittipaldi, J.J., and M.J. Romanos, "Environmental Analysis with the Environmental Impact Computer System (EICS)," Bureau of Urban and Regional Planning Research, Planning and Public Policy, IX, No. 2 (November 1983), 6 pp.

Fittipaldi, J.J., Army Regulation (AR) 200-2, Environmental Effects of Army Actions, Headquarters, Department of the Army, Environmental Office (effective 23 January 1989.)

Fittipaldi, J.J., *Guidelines for Review of EA / EIS Documents*, USACERL Report N-92, August 1980. ADA089976.

Sets forth a systematic procedures for a review and evaluation of EA/EIS documents for Administrative Compliance, General Document, and Technical Review; and outlines a procedure to prepare a review summary of EA/EISs, which will lead to an ultimate recommendation on the technical adequacy and completeness of those documents. This report should help in meeting the requirements of Army Regulation 200-2, which has imposed stringent requirements for compliance with the National Environmental Policy Act.

Fittipaldi, John J., *Computer-Aided Environmental Impact Analysis for Army Real Estate Actions: User Manual*, USACERL Report N-70, April 1979. ADA068746.

Fittipaldi, John, Susan Thomas, Robert Lacey, Robert Baran, Lynn Engelman, and Robin Goettel, *Procedures for Environmental Impact Analysis and Planning*, TR N-130, October 1982. ADA122417.

Analyzes the environmental assessment process, including identification of the type of action being considered by an Army facility, planning, scoping, timing, preparing environmental documents, and identifying monitoring and mitigation procedures. Various required environmental documents which the Army must prepare were identified and described, including staffing and coordination requirements.

Lozar, R.C., and H. Balbach, *The Environmental Early Warning System (EEWS): Concept Description*," USACERL Technical Report N-144, U.S. Army Construction Engineering Research Laboratory, January 1983. ADA122356.

Shows a concept description of EEWS: an interactive computer system designed to give the Department of the Army Headquarters and Major Command planning and decision-making personnel a way to quickly find potential environment-related problems associated with proposed changes in troop strength, mission, facilities, natural resource management, and land use. Included are a system description from the user's point of view, a brief explanation of how the system calculates results, and descriptions of the system's tabular and location-specific data handling capabilities.

Riggins, Robert E., "Comprehensive Computer-Aided Environmental Impact Analysis", *J. Environmental Systems*, Vol 10(1), 1980-81.

Riggins, Robert E., and E.D. Smith, *Aquatic Rational Threshold Value (RTV) Concepts for Army Environmental Impact Assessment*, USACERL Technical Report N-74, Jul 1979. ADA073032.

Presents the results of a study undertaken to develope practical techniques for evaluating the "significance" of predicted water quality impacts. The term "significant" is discussed, existing aquatic ecosystem models are reviewed, potential criteria for measuring significance are examined and the concept framework is presented. The result is a Rational Threshold Value concept for measuring the significance of impacts on aquatic features.

Schomer, Paul D., Report of CHABA-WG-69, Guidelines for Preparing Environmental Impact Statement on Noise, National Academy of Science, 1978.

Whitworth, W.R., D.L Price, and H.E. Balbach. 1992. *Using the Land Condition-Trend Analysis Program for EIS Documentation*. 84th Annual Meeting, American Society of Agronomy, Minneapolis, MN. Agronomy Abstracts, p.11

Discusses the use of LCTA to assist in EIS preparation for the Camp Shelby EIS study discussed above in area 10A.

Area 11: Environmental Modeling in Land Management Applications and Related Geographic Information System (GIS) Technology

As a general goal, current research efforts within USACERL and with associated university partners are designed to develop the ability to rapidly design and implement training-area-specific simulation models in support of installation land management. Initially, the spatial analysis performed was limited to that of the Geographic Information System (GIS) type. At its initiation, in the 1970s, such capabilities were close to state-of-the-art. A major series of efforts at USACERL led to the development of the Geographic Resources Analysis Support System (GRASS) GIS programs. They have been used extensively throughout the Army and by many other Federal and state agencies for analysis and management of land resource conflicts. GIS systems, however, have not had the capability to model phenomena across time in a manner required to meet emerging environmental planning goals.

A formal integration of ecological and landscape process models is required to more fully realize the implication of thousands of reports documenting the results of decades of land management oriented research and development. For the most part, this takes place in the mind of the professional land managers, trainers, and environmental specialists. These reports involve such things as fundamental ecosystem sustainability, inherent ecological processes, local and regional biodiversity, threatened and endangered species (TES), and compliance issues. Each results in a picture—a model—of a small component of the landscape. Each model is actually a submodel of the entire system. The integration of these reports (these models) is accomplished today through the educational background and experience of dedicated land managers.

The challenge is to design a dynamic, spatial, ecological modeling and simulation software capability for the support of TES and biodiversity simulations. The target application is understanding, through simulation, the relationships between the training, TES habitat, and biodiversity. Ultimately, these tools will assist in the development of dynamic, spatial, ecological and biodiversity models of the Mojave region, a high-priority ecoregion heavily committed to defense uses.

Another goal is to develop new collaborative tools and approaches for human-human, human-computer, and computer-computer interactions, and to extend the design and prototype of existing simulation models. The development of state of the art multi-model software environment, incorporating collaborative human/computer interactions, and spatially and temporally explicit ecosystems is progressing within the context of the efforts listed in the bibliography for this area.

Because of the dynamic nature of the research within this area, many of the citations in Area 11B do not follow the format used for printed, paper documents. A large number of the products referenced are available only through postings on the World Wide Web or through Internet e-mail requests to the principal author. We have chosen to incorporate such listings because of their importance to the knowledge within the field, and with the understanding that some readers may not be able to access them. We apologize to those readers. Since, however, a majority of the people accessing this document will be doing so via the WWW in any case, this was felt to be an acceptable compromise.

11A: Applicable Results

Goran, W.D., and R.E. Riggins, 1983, "Geographic Information Systems for Training Land Evaluation," Army R, D & A (Research, Development and Acquisition), September/October 1983, pages 26-28,

Goran, W.D., and W.D. Severinghaus, 1991, "Integrating Land Management and Training Through ITAM and GRASS," The Military Engineer, July-August 1991.

Goran, W.D., W. Fredrick Limp, Michael Shapiro and James Westervelt, 1991, GRASS User's Guide, Version 4.0.

Johnson, M.O., and W.D. Goran, *Sources of Digital Spatial Data for Geographic Information Systems*, USACERL. Technical Report. N-88/01, Dec 1987. ADA189788.

Identifies digital data sources to help installations evaluated the feasibility of implementing systems such as GRASS (Geographic Resources Analysis Support System), which requires digital spatial data. Included is a list of the following characteristics for each source: format, scale/resolution, coverage, media, costs, and a textual description.

Johnson, M. O., Goran, W.D., and M. Shapiro, 1985, Land Management Applications Using Aerial Photography in GIS, 77th Annual Meeting of the American Society of Agronomy, Chicago, IL, December, 1985.

Shapiro, Michael, "User's and Programmer's Manual for the Geographical Resources Analysis Support System," 1987, 1988, 1991. This 800-page handbook is used as a text by universities for teaching GRASS.

Tazik, David J., Cindy A. Abrahamson, Victoria C. Harmon, and William D. Goran, "Endangered Species Habitat Analysis Using the GRASS Geographic Information System," Agronomy Abstracts, Annual Meeting of the American Society of Agronomy, San Antonio, TX (Abstract on page 12), Oct 1990.

Warren, S.D. and C. F. Bagley. 1992. SPOT imagery and GIS support of military land management. Geocarto International. Volume 7(1):35-43.

Warren, Steven D., Mark O. Johnson, Goran, W.D., and Victor E. Diersing, 1990, "An Automated, Objective Procedure for Selecting Representative Field Sample Sites," Photogrametric Engineering and Remote Sensing, Vol. 56, No. 3, March 1990, pp. 333-335.

11B: Underlying Research Information

Bradshaw, S. and P.J. Thompson; Options for acquiring elevation data. Jan 1989. ADP Report. N-89/20. ADA220934.

Presents a short evaluative summary of the digital elevation products available from: (1) The Defense Mapping Agency, (2) The U.S. Geological Survey, and (3) private companies. Digital elevation data are crucial for GRASS applications that demand the ability to create useful, accurate, and current digital map layers.

Buehler, K.A., M. Shapiro, and J.D. Westervelt, *Prediciting Database Requirements for Geographic Information Systems in the Year 2000: Long-Term Design Issues for GRASS*, USACERL Technical Report EC-92/01, August 1992. ADA256862.

Explores ways in which the GRASS geographic information system might be improved in capability. Of the many possibilities, the highest-rated options were to link the spatial database to a relational dbms or to an object-oriented dbms.

This would enhance management of voluminous non-spatial elements while retaining association with the spatial context.

Goran, W.D., L.L. Radke, and W.D. Severinghaus, *An Overview of the Ecological Effects of Tracked Vehicles on Major US Army Installations,"* 75p., USACERL Technical Report N-142, February 1983. ADA126694.

Various levels of field studies were done on 12 U.S. Army Training Doctrine Command (TRADOC) and U.S. Army Forces Command (FORSCOM) installations to provide a general overview of ecological disturbance cause by tactical vehicle training. Detailed quantitative and qualitative data were obtained from Forts Polk, Knox, Hood, and Lewis; supplementary semi-quantitative and qualitative studies were done at Forts Benning, Bliss, Carson, Drum, Irwin, Riley, and Stewart, and at Yakima Firing Range.

Lozar, R., ed., *Proceedings of the 1988 GRASS User Group Meeting*, USACERL Technical Manuscript N-89/18, September 1989. ADA213823.

Presents papers from the 1988 Annual Grass User Group Meeting. Grass is a land management support tool originally developed to help military installations ensure realism in training while conserving the environment. The papers are group as follows: applications, data concerns, and integration of GRASS with other packages.

Lozar, Robert C., "Global Climatic Change Management by Watershed Basin Units," Proceedings of *the XVII International Society of Photogrammetry and Remote Sensing*, Washington D.C., August 1992.

Lozar, Robert C., C. Ehlschlaeger, Jahn, Paul, "Hydro-Environmental Zones: The Key Unit for Global Change Monitoring", Proceedings of *the GRASS User Group Conference*, National Park Service, Denver CO, March 1992. Published as Tech Report NPS/HRGISD/NRTR-93/13 August 1993.

McKay, E.D.; R.R. Pool; L.R. Smith; R.J. Krumm; S.L. Denhart; G.D. Taylor; B.J. Stiff. 1990. Unraveling complex geologic settings using GIS. Environmental Systems Research Institute 1990 Mapbook, Environmental Systems Research Institute, Redlands, CA.

Neidig, C.A., D.P. Gerdes, and C. Kos, *GRASS 4.0 Map Digitizing User's Manual: v.digit*, USACERL ADP Report EGI-92-01, July 1992. ADA256859.

GRASS is a GIS system designed to be used to manage Army training lands, among other applications. The program used within GRASS 4.0 to convert analog map tracings to digital form is called *v.digit*. The manual discusses the use of this program, including its many options. Drivers exist to use *v.digit* with many digitizing tablets in a workstation or X Windows environment.

Senseman, G.M., C.F. Bagley, and S. Tweddale, *Accuracy Assessment of Discrete Classification of Remotely Sensed Digital Data for Landcover Mapping*. USACERL Technical Report EN-95/04, April 1995. ADA296212.

Compares site-specific and non site-specific accuracy assessment analyses in the context of deriving a general landcover map using remotely-sensed digital data. Non-site-specific analysis detected only gross errors. Site-specific analysis provided critical information about a classes' locational accuracy. The use of a Kappa Coefficient of Agreement and an error matrix were found to enhance accuracy, and their use should be included in the documentation accompanying the classification.

Shapiro, M., C. Bouman, and C.F. Bagley, *A Multiscale Random Field Model for Bayesian Image Segmentation*. USACERL Technical Report EC-94/21, June 1994. ADA283875.

Shapiro, Michael, and J.D. Westervelt, "GRASS Imagery - GRID interface," published in *Mapping from Modern Imagery, Acquisition and Revision of Spatial Information*, Proceedings of the International Symposium on Mapping from Modern Imagery, International Society for Photogrammetry and Remote Sensing, Edinburgh, Scotland, September 1986.

Zhuang, H.C., M. Shapiro, and C.F. Bagley. 1993. "Relaxation vegetation index in non-linear modelling of ground plant cover by satellite remote-sensing data," *Int. J.Remote Sensing*. Vol 14(18):3447-3470.

Agee, J. (1989), "A Geographic Analysis of Historical Grizzly Bear Sightings in the North Cascades," *Photogrammetric Engineering and Remote Sensing*, 55(11), 1637-1642.

Historic grizzly bear sightings in the North Cascades area of Washington were analyzed using the GRASS geographic information system (GIS) software. A 22-class land-cover database that was determined to be 85 percent accurate was compared to 91 historic settings of grizzly bears. The historic settings were positively associated with the whitebark pine - subalpine larch and subalpine herb cover types. The sighting locations were found to have similar land-cover richness but land-cover interspersion different from the overall landscape within the study area. These data were used to develop new map layers for relative cover type and diversity selection, which were then combined into a map of sighting potential for grizzly bears in the North Cascades.

Andersen, M.C., and Mahato, D. (1995). "Demographic models and reserve designs for the California Spotted Owl," *Ecological Applications*, 5(3), 639-647.

Presents results from two demographic models of the California Spotted Owl. The first model is based on a simple formulation of a birth-death process; the second model is a somewhat more detailed simulation model. The models are intended to provide a comparison of the SOHA and HCA reserve-design strategies. We are particularly interested in the ability of the two reserve designs to withstand recurring environmental catastrophes in the form of forest fires. The HCA strategy always leads to longer persistence times than the SOHA strategy. The essential difference between the two strategies appears to lie in the shape of the function that gives the probability of colonization of an empty nest site.

These results have several implications for the conservation of California Spotted Owls and for conservation biology in general. Some variant of the HCA reserve design strategy may be preferable to the interim strategy being proposed for conservation of the California Spotted Owl. Simple, parameter-sparse models like ours can yield results comparable to those of more complex and detailed models. Models that include the effects of catastrophic environmental perturbations have great potential for application in conservation biology.

Armstrong, M.P., and P.J. Densham, (1992). "Domain decomposition for parallel processing of spatial problems," *Computational, Environmental and Urban Systems*, 16, 497-513.

Spatial models often are not used to their fullest potential because they have massive computational requirements. Existing workstations and microcomputers often must solve these models in batch mode and, consequently, decisionmakers are unable to explore and resolve complex spatial problems in an interactive and graphical environment similar to that provided by general purpose business software. Parallel processing can solve spatial models at high speed, greatly decreasing turnaround times and enabling decisionmakers quickly to see results of revising parameters and criteria. To reap these benefits in a parallel processing environment, researchers must recast modeling procedures from their existing sequentially-oriented form to one in which parallelism can be exploited. This process, referred to as domain decomposition, is a fundamental enterprise in parallel spatial modeling. Domain decomposition for spatial problems can be structured by a set of general principles that are described and illustrated using an example from location-allocation modeling.

Baker, W.L., S.L. Egbert, and G.F. Frazier, (1991). "A spatial model for studying the effects of climatic change on the structure of landscapes subject to large disturbances," *Ecological Modeling*, 55, 109-125.

Global warming may have many consequences for natural ecosystems, including a change in disturbance regimes. No current model of landscapes subject to disturbance incorporates the effect of climatic change on disturbances on decade to century time scales, or addresses quantitative changes in landscape structure as disturbances occur. A new computer simulation model, DISPATCH, which makes use of a geographical information system for managing spatial data, has been developed for these purposes. The concept and structure of the DISPATCH model are described here, and a hypothetical example of its use is illustrated; but the model requires refinement before it can be used to predict the effects of global warming on specific landscapes. The model includes provisions for (1) temporally varying weather conditions and their effect on disturbance sizes, and (2) the effect of spatial variation in vegetation condition and physical setting on the probability of disturbance initiation and spread. The potential use of the model is illustrated with a hypothetical example in which the age structure of disturbance patches is monitored for a 250-year period as weather fluctuates. The model run suggests that landscape structure fluctuates even if a disturbance regime remains constant.

Battaglin, W.A., G. Kuhn, and R. Walker, (1993). "Using a GIS to Link Digital Spatial Data and the Precipitation-Runoff Modeling System, Gunnison River Basin, Colorado," in *Second International Conference/Workshop on Integrating Geographic Information Systems and Environmental Modeling*. Breckenridge, Colorado: National Center for Geographic Information and Analysis.

The U.S. Geological Survey Precipitation-Runoff Modeling System, a modular, distributed-parameter watershed-modeling system, is being applied to 20 smaller watersheds within the Gunnison River basin. The model is used to derive a daily water balance for subareas in a watershed, ultimately producing simulated streamflows that can be input into routing and accounting models used to assess downstream water availability under current conditions, and to assess the sensitivity of water resources in the basin to alterations in climate. A geographic information system (GIS) is used to automate a method for extracting physically based hydrologic response unit (HRU) disturbed parameter values from digital data sources, and for the placement of those estimates into GIS spatial data layers. The HRU parameters extracted are: area, mean elevation, average land-surface slope, predominant aspect, predominant land-cover type, predominant soil type, average total soil water-holding capacity, and average water-holding capacity of root zone.

Bennet, D., M.P. Armstrong, and F. Weirich, (1993). "An object-oriented modelbase management system for environmental simulation," in *Second International Conference/Workshop on Integrating Geographic Information Systems and Environmental Modeling*. Breckenridge, Colorado: National Center for Geographic Information and Analysis.

Describes the design and implementation of a geographical modeling system (GMS) that facilitates the construction and use of dynamic environmental simulation models. The GMS provides an operational framework in which spatial knowledge can be stored and managed, theory can be modeled and tested, and alternative resource management strategies can be evaluated. Our goal is to provide users with the materials and tools needed to construct sophisticated geographic models that accurately represent both the structure and behavior of natural systems. To accomplish this goal we employed object-oriented analysis and design methods to integrate modelbase management and GIS technologies into a single system.

Berich, R.H., and M.B. Smith, (198-) LANDSAT and MICRO-GIS for Watershed Modeling. Purdum and Jeschke, Consulting Engineers. 1029 North Calvert Street, Baltimore, MD 21202.

A microcomputer-based Geographic Information System (GIS) incorporating LANDSAT of other remotely sense digital data will greatly reduce the cost of watershed modeling. The GIS will provide the ability to create a cartographic data base that can be merged with other data, including demographic data, and used for many other planning purposes. All data can be efficiently maintained and updated.

The computation of hydrologic parameters such as Soil Conservation Service (SCS) runoff curve numbers is a significant task in watershed modeling. The GIS eliminates manual computation of SCS runoff curve numbers and SCS subbasin lag. Statistics for percentage of land use, soil types, and slope categories are produced in report format. GIS data is input directly into hydrologic models such as TR-20, HEC-1, and others.

Berry, J.K. (1986). "Learning computer-assisted map analysis," *Journal of Forestry*, 84(10), 39-43.

Provides good general background in GIS.

Berry, J.K. (1987). "A mathematical structure for analyzing maps," *Environmental Management*, 11(3), 317-325.

Provides good background in GIS.

Berry, J.K. (1987). "Fundamental operations in computer-assisted map analysis," *International Journal of Geographic Information Systems*, 1(2), 119-136.

Provides good background in GIS.

Berry, J.K. (1987). "Computer-assisted map analysis: a set of primitive operators for a flexible approach," in *ASPRS-ACSM Annual Convention*, 1 . Baltimore.

Provides good background in GIS.

Berry, J.K. (1987). "Computer-assisted map analysis: potential pitfalls," *Photogrammetric Engineering and Remote Sensing*, 53(10), 1405-1410.

Provides good background in GIS.

Betancourt, T.L., and K.M. Strzepeck, A GIS extension to the early warning system for Boulder Creek, Colorado. Center for Advanced Decision Support for Water and Environmental Sciences, University of Colorado, Boulder.

A model for predicting floods.

Botkin, D.B., J.F. Janak, and J.R. Wallis, (1972). "Some ecological consequences of a computer model of forest growth," *Journal of Ecology*, 60, 849-872.

Presents a computer simulation of forest growth that successfully reproduces the population dynamics of the trees in a mixed-species, mixed-aged forest of northeast North America. The simulator is designed to be used in the Hubbard Brook Ecosystem Study and to provide output in the same form as the original vegetation survey of that study. Underlying concepts of the simulation are general.

Brandt, S.P., D. Mason, A. Goyke, K. Hartman, J. Kirsch, and J. Luo, (1993). "Spatially-explicit ecological modeling of fish: Underwater views of functional attributes of the aquatic model," in *Second International Conference / Workshop on Integrating GIS and Environmental Modeling*. Breckenridge, Colorado.

Spatially-explicit models and dynamic spatial models can provide unique insights into the effects of spatial patterning in the environment on ecological processes. Spatial modeling has rarely been applied in aquatic systems because of the difficulty of measuring biological patchiness under the water's surface. In this paper we exploit the spatial information inherent in acoustic data to evaluate how spatial patterning in the aquatic habitat might affect functional attributes of the environment. Underwater acoustics provides spatially-explicit models are created by subdividing the aquatic habitat into small homogenous units that define a grid of horizontal distance and water depth. We reduce the spatial cell to a small enough size (e.g., 0.5m x 20m) so that assumptions of homogeneity can be met. Each cell in the grid is characterized by a set of measured attributes including prey density, prey size, and water temperature. Ecological models of the same model structure are run in each cell, but are parameterized differently according to the habitat conditions in each cell. Foraging, behavioral and bioenergetics models convert measured prey densities and sizes into estimates of the predator's growth rates. The result is a cross-sectional map of potential growth rates of a predator that integrate the predator's physiological needs and behavior with the prevailing conditions of the physical habitat and food supply. Data visualization techniques are used to display these spatial patterns of fish growth rates to gain a better understanding of spatial processes.

Brimicombe, A.J., and J.M. Bartlett, Linking Geographic Information Systems with Hydraulic Simulation Modeling for Flood Risk Assessment: the Hong Kong Approach. [Allan Brimicombe: lsajbrim@hkpcc.hkp.hk].

Hong Kong's northern lowland basins have undergone substantial urban and sub-urban development over a 20-year period. This has been associated with worsening recurrent flood problems. An approach has been adopted whereby hydraulic modeling has been used in conjunction with geographic information systems (GIS) to produce 1:5000 scale Basin Management Plans. GIS has a dual role: in data modeling; in data interpolation, visualization and assessment of flood hazard and flood risk using the outputs from the hydraulic modeling. By using current land use and various development scenarios to be modeled over a range of rainstorm events, "what if" decision support can be used in devising Basin Management Plans. Linking with hydraulic modeling requires a different approach to GIS data modeling than with the more traditional linkage with hydrological modeling only. The methodology developed in Hong Kong is presented as a case study.

Brown, W.M., M. Astley, T. Baker, and H. Mitasova, (1995) *GRASS as an integrated GIS and visualization system for spatio-temporal modeling*. In: ACSM/ASPRS Annual Convention & Exposition Technical Papers, Vol. 4.

Increasingly, geoscientific data is being measured in three dimensional (3D) space and time for studies of spatial and temporal relationships in landscapes. To support the analysis and communication of these date, a new approach to cartographic modeling is emerging from the integration of computer cartography and scientific visualization. This approach, in this paper called multidimensional dynamic cartography (MDC), is based on viewing data processed and stored in a Geographical Information System (GIS) in 3D space and visualizing dynamic models of geospatial processes using animation and data exploration techniques. Such techniques help researchers refine and tune the model in addition to making the model easier for others to understand. We describe various aspects of MDC implementation within GRASS GIS and illustrate its functionality using example applications in environmental modeling. Images, animations and other work associated with this paper may be viewed on the World Wide Web at URL: http://www.cecer.army.mil/grass/viz/VIZ.html

Buckley, D.J., M. Coughenour, C. Blyth, D. O'Leary, and J. Bentz, (1993). "The Ecosystem Management Model Project: Integrating Ecosystem Simulation Modeling and ARC/INFO in the Canadian Parks Service," in *Second International Conference / Workshop on Integrating Geographic Information Systems and Environmental Modeling*. Breckenridge, Colorado: National Center for Geographic Information and Analysis.

Carver, S., I. Heywood, and S. Cornelius, (1994). Evaluating field-based GIS for environmental characterization, modeling and decision support. School of Geography, University of Leeds.

Examines the potential of using GIS in the field for experimental characterization and modeling in isolated areas. Observations are based on experiences gained during two Anglo-Russian expeditions to the Altai Mountains of Siberia aimed at evaluating proposals for a new national park in the Katunsky Ridge area of the Belukha Massif. The use of GIS together with GPS, EDM surveying equipment, and portable data loggers for primary data collection and verification/update of existing data is described and the use of field-based systems for on-the-spot modeling and decision support is evaluated. Despite disadvantages associated with taking sensitive equipment into a harsh environment, adopting an integrated approach to data collection and database creation holds greater attractions of interactive feedback from field surveys and ground truthing. This is enhanced by the provision of more accurate data derived from field surveys and local knowledge than would be possible from studies based on maps and remotely sensed imagery alone. Conclusions from the study are expanded in terms of GIS decision support for relief planning and response management where up-to-date field information may be important.

Caswell, H., J.E. and Cohen, (1991). "Disturbance, interspecific interaction, and diversity in metapopulations," *Biological Journal of the Linnean Society*, 42, 193-218.

Metapopulation diversity patterns depend on the relations among the timescales of local biological interactions (predation, competition), the rates of dispersal among local populations, and the patterns of disturbance. We investigate these relationships using a family of simple nonlinear markov chain models. We consider three models for interspecific competition; if the species are identified with early and late successional species, the models describe the facilitation, inhibition, and tolerance models of ecological succession. By adding a third competing species we also compare transitive competitive hierarchies and intransitive competition networks. Finally, we examine the effects of predation in mediating coexistence among competing prey species.

Clarke, K.C., G. Olsen, and J.A. Brass, (1994). Refining a cellular automaton model of wildfire propagation and extinction. Department of Geology and Geography, Hunter College and CUNY; NASA Ames Research Center, Moffett Field, CA.

In previous work, a cellular automaton-based model was designed to simulate the propagation and extinction behavior of wildfire. Research on the model has now moved from prototyping and calibration to refinement using more sophisticated data from remote sensing, field data collection with GPS, and extension to forest as well as range fires. Data collected in 1993 was used to classify and model the fuel properties of an extensive area in the Santa Cruz Mountains, California. The area includes several State Forests and habitat protection districts, contains extensive stands of uncut Douglas fir and coastal redwood, and is particularly susceptible to fire. Accurate fuel characterization, coupled with model-based estimates of fuel moisture conditions were used as input to the Monte Carlo version of the fire model. Data have been classified, geometrically and radiometrically corrected, ground truth checked, and integrated with the fire risk maps and assessments, which can be used to assist in planning for fire risk management in the Santa Cruz mountains. Issues related to model limitations, data accuracy, data integration, and fire risk management are discussed. The integration of data, both real and modeled, with the cellular automaton prediction to make risk maps is seen as an effective and inexpensive means by which intelligent wildland management can be coupled with remote sensing to save life and property, and to protect biological diversity and land resources.

Costanza, R., H.C. Fitz, J.A. Bartholomew, and E. DeBellevue, *The Everglades Landscape Model (ELM): Summary report of Task 1, Model Feasibility Assessment*, Environmental and Estuarine Studies, University of Maryland System, 1992.

Costanza, R., and T. Maxwell, (1991). "Spatial ecosystem modeling using parallel processors," *Ecological Modeling*, 58, 159-183.

Costanza, R., and F.H. Sklar, (1985). "Articulation, accuracy and effectiveness of mathematical models: a review of freshwater wetland applications," *Ecological Modeling*, 27, 45-68.

Costanza, R., F.H. Skylar, and M.L. White, (1990). "Modeling coastal landscape dynamics," *BioScience*, 40, 81-98.

Craig, P.M., and G.A. Burnette, Basinwide water quality planning using the QUAL2E model in a GIS environment. Environmental Consulting Engineers, Inc. [P.O. Box 22668, Knoxville, TN 37933].

EPA-developed water quality model that has gained wide acceptance as a planning tool. Model can simulate up to 15 constituents, including DO, BOD, COD, T, NH4, N2, coliform. Paper examines the issues relevant in using the model for water quality planning in a GIS environment.

Cronshey, R.G., F. Theurer, and R.L. Glenn, (1993). GIS-Water quality computer model interface: a prototype. Soil Conservation Service, U.S. Department of Agriculture.

SCS is adopting several Agricultural Research Service (ARS) water quality models and is building an interface connecting geographically referenced watershed data (both spatial and tabular) to the models via control of the model user. Relational database attribute data for the models will be associated with eight GIS data layers (soils, field, elevation, watershed boundary, subwatershed, geomorphic, stream network, point data).

Cuddy, S.M., J. Richard Davis, and Peter A. Whigham (1993). "An examination of integrating time and space in an environmental modelling system," in *Second International Conference/Workshop on Integrating Geographic Information Systems and Environmental Modeling*. Breckenridge, Colorado: National Center for Geographic Information and Analysis.

An integrated system, LMAS, using the ARC/INFO GIS, a soil moisture model, and an expert system has been developed and installed at Puchapunyal Army Range, Australia, to predict the environmental damage from training exercises. The problem required both temporal and spatial modeling. It was not possible to develop LMAS entirely within the GIS for both efficiency and functionality reasons. The paper describes the system design, some shortcomings of current GIS and identifies some idealized features of a GIS that would allow truly embedded temporal and spatial modeling suitable for such environmental management tasks.

D'Agnese, F. A., A.K. Turner, and C.C. Faunt (1993). "Using geoscientific information systems for three-dimensional regional ground-water flow modeling in the Death

Valley region, Nevada and California," in *Second International Conference/ Workshop on Integrating Geographic Information Systems and Environmental Modeling*. Breckenridge, Colorado: National Center for Geographic Information and Analysis.

Three-dimensional ground-water modeling of the complex Death Valley hydrologic basin requires the application of a number of Geoscientific Information System (GSIS) techniques. This study, funded by U.S. Department of Energy as a part of the Yucca Mountain Project, typical of the Basin and Range province; a variety of sedimentary and igneous intrusive and extrusive rocks have been subjected to both compressional and extensional deformation. GSIS techniques allow the systhesis of geologic, hydrologic and climatic information gathered from numerous sources. Integration of these data facilitates the development of detailed spatial models that can be used for distributed-parameter modeling. Construction of a 3-dimensional hydrogeologic framework model and definition of surface and subsurface hydrologic conditions are possible with the combined use of software products available from several vendors, including traditional GIS products and sophisticated contouring, interpolation, visualization and numerical modeling packages.

DeAngelis, D.L. (1975). "Stability and connectance in food web models," *Ecology*, 56, 238-243.

Computer studies by Gardner and Ashby (1970) show that large randomly connected systems have a decreasing probability of being stable as the number of connections increases. These conclusions are not appropriate to some plausible food web models. If the food web is characterized by low assimilation efficiencies, a bias toward strong self-regulation of higher trophic level species, or a bias toward donor dependence, the probability of stability can increase with increasing connectance.

Ebenhard, T. (1991). "Colonization in metapopulations: a review of theory and observations," *Biological Journal of the Linnean Society*, 42, 105-121.

In metapopulation dynamics turnover of populations may be frequent. Regional survival of species in such a system with frequent extinction hinges on its colonization ability. Colonization is more than just dispersal; when a propagule reaches a new patch it faces higher extinction probabilities than does an established population. Extinction models as well as empirical data suggest that a large propagule with potential for rapid increase in a varying environment , or with a low mortality rate in an environment perceived as constant, has a higher probability of successful colonization.

Fahrig, L., and G. Merriam, (1985). "Habitat patch connectivity and population survival," *Ecology*, 66, 1762-1768.

Describes a patch dynamics model which can be used to simulate the changing sizes of resident populations in a series of interconnected habitat patches. We applied the model to white-footed mice (Peromyscus leucopus) inhabiting patches of forest in an agricultural landscape. The model predicts that mouse populations in isolated woodlots have lower growth rates and are thus more prone to extinction than those in connected woodlots. Field data support this prediction.

Fedra, K. (1993). "Distributed models and embedded GIS: Strategies and Case Studies of Integration," in *Second International Conference/Workshop on Integrating Geographic Information Systems and Environmental Modeling*. Breckenridge, Colorado: National Center for Geographic Information and Analysis.

There are several strategies and approaches for the integration of spatially distributed environmental models, including expert systems, and GIS. They range from simple pre- and post-processor linkage through shared data files to building models as complex analytical functions into fully functional GIS, or embedding required GIS functionality in spatially distributed models.

Following an overview of integration strategies and their relative merits, this paper describes a number of applications that use a tight coupling of GIS functionality with environmental models, integrated into a common graphical user interface. These systems exemplify the high degree of flexibility that can be achieved with generic low-level building blocks in an object oriented design.

Databases, simulation and optimization models, expert systems, and GIS functionality together with hypertext and multi-media elements can effectively be configured in user-friendly environmental decision support systems that are problem specific and customized for individual institutions or user groups.

Examples include a global change information assessment system, air quality management tools, water resources and river basin management systems (including surface and groundwater quality as well as coastal marine models), and systems for environmental impact assessment and technological risk analysis. The examples illustrate principles and strategies of integration, and indicate desirable features of next generation of integrated GIS and models.

Frysinger, S.P., D.A. Copperman, and J.P. Levantino, Environmental decision support systems: an open architecture integrating modeling and GIS. AT&T Bell Laboratories, Holmdel, New Jersey. [spf@hoqaa.att.com].

The information-intensive nature of environmental management has led to increased interest in a class of computer applications called Environmental Decision Support Systems (EDSS). These are systems designed to assist humans making complex environmental management decisions, employing multiple technologies to accomplish this goal. As defined here, EDSSs are focused on specific rather than generic problems in order to provide a user interface that is sufficiently rich yet simple enough to encourage casual users. This is in sharp contrast to the general purpose character of such software systems as Geographic Information Systems (GIS), though the spatial nature of environmental management problems virtually dictates the use of GIS technology in any EDSS. Therefore, extensible software architectures supporting customization toward various decision problems and integration of various support tools (including GIS) will be required if EDSSs are to rise to the occasion of our environmental stewardship imperative. We briefly describe such an architecture, with special emphasis on the mechanisms by which a variety of mathematical modeling programs are integrated with the GRASS GIS and a graphical user interface to yield a single coherent system that is easily adapted to a wide variety of decision problems.

Gardner, R.H., M.G. Turner, R.V. O'Neill, and S. Lavorel, (1991). "Simulation of the scale-dependent effects of landscape boundaries on species persistence and dispersal," in P.G.R. and R.J. Naiman (eds.), *The Role of Landscape Boundaries in the Management and Restoration of Changing Environments* (pp 76-89). New York: Chapman and Hall.

The relationships between life history characteristics and broad-scale patterns of species abundance were investigated with a model that simulates the dispersal of populations through heterogeneous landscapes. Movement was simulated on randomly generated landscapes and on forested landscapes digitized from aerial photographs. Simulation results indicated that population abundances will change suddenly near the critical threshold in habitat connectivity as predicted from percolation theory. The existence of critical thresholds is important for many management and conservation issues, but these thresholds suggest that data are required at spatial scales that are specific to the dispersal characteristics of the simulated population.

Gessler, P.E., I.D. Moore, N.J. McKenzie, and P.J. Ryan, (1993). "Soil-landscape modeling in southeastern Australia," in *Second International Conference/ Workshop on Integrating Geographic Information Systems and Environmental Modeling*. Breckenridge, Colorado: National Center for Geographic Information and Analysis.

Explicit and quantitative soil-landscape models are required for environmental modeling and management. Advances in the spatial representation of hydrological and geomorphological processes using terrain analysis techniques are integrated with the development of a sampling and soil-landscape model building strategy. Preliminary results are encouraging and show useful predictive relationships between terrain and soil attributes. These techniques may provide a more appropriate methodology for the spatial prediction and understanding soil-landscape processes.

Giles, R.H., and Weihung Tsui (1987). "A regional system: The land use guidance system," in *International Workshop on Geographic Information Systems*, pp 216-247. Beijing, China: Grimmond, C.S.B. Dynamically determined parameters for urban energy and water exchange modeling.

An introductory design for a land use guidance system. A land use guidance system is a comprehensive program with an optimum mix of hardware, staff, programs, data facilities and special components that, as a whole, provides aids to making decisions about complex land uses within a region. A guidance system unifies (1) an objectives system, (2) a geographic information system, (3) a textual and numerical information system, (4) a text processing system and network, (5) another-reports system, and (6) a management group with (7) decision makers, and (8) citizens.

Hannon, B., R. Costanza, and R. Ulanowicz, (1991). "A general accounting framework for ecological systems: a functional taxonomy for connectivist ecology," *Theoretical Population Biology*, 40(1), 78-102.

Accounting of material and energy flows has long been an important tool in ecosystem ecology. But each material is usually handled separately and independently. The connections between materials, energy, plants, animals, etc. have not been incorporated into the accounting framework, and "service" or information flows (such as flower pollination by bees) are usually ignored. We develop a general accounting framework that addresses this deficiency. In our framework, each connection (both physical and informational) can be unambiguously assigned, quantified and qualified, and an input-output balance is easily

checked and maintained for each product. Costly independent data collections can be integrated into this common framework to amplify their original usefulness and provide the investigator or ecosystem manager with enhanced understanding of the entire ecosystem from which they were taken. The integrated data also allow various ecosystem models to be constructed efficiently, without unnecessary and costly duplication of effort. We present detailed guidelines for construction of such a framework, followed by examples and applications.

Hannon, B., and C. Joiris, (1989). "A seasonal analysis of the southern North Sea ecosystem," *Ecology*, 70(6), 1916-1934.

This report documents an input-output model of the southern North Sea ecosystem to determine the relationships between 10 biotic and abiotic stock levels and to investigate how their direct and indirect dependency changed through the typical year. Our method allows ecologists to extend their understanding of connection in an ecosystem. The method captures not only the food source connection but also those species that contribute to the food source, those at the next level that contribute to those sources, and so on, until all exchanges have been assigned without ambiguity.

Hardin, J. (1992). Developments in large scale simulation team environments at the National Center for Supercomputing Applications. National Center for Supercomputing Applications, University of Illinois, Urbana-Champaign.

Reports on work with large-scale computational science teams, and the development of software to deal with a number of the problems they confront, including large, heterogeneous data set file structures and data management facilities for manipulation of simulation and observational data in a heterogeneous system environment, and automated simulation model generation and the movement to parallel systems. This includes system development by transparently moving Stella models to high performance systems like Crays and Connection Machines, to facilitate the construction of large scale models. It will demonstrate one means for the globally distributed groups modeling global economic and ecological change to productively interact in real time with remote colleagues in discussions involving simulation modeling, data exchange and analysis, and general image, animation and information exchange.

Hastings, A. (1991). "Structured models of metapopulation dynamics," *Biological Journal of the Linnean Society*, 42, 57-71.

Models of metapopulation dynamics that describe changes in the numbers of individuals within patches are developed. These models are analogous to structured population models, with patches playing the role of individuals. Single species models that do not include the effect of immigration on local population dynamics of occupied patches typically lead to a unique equilibrium. The models can be used to study the distribution of numbers of individuals among patches, showing that both metapopulations with local outbreaks and metapopulations without outbreaks can occur in systems with no underlying environmental variability.

Hay, L., Loey Knapp, and Janet Bromberg (1993). "Integrating geographic information systems, scientific visualization systems, statistics, and an orographic precipitation model for a hydro-climatic study of the Gunnison River basin, southwestern Colorado," in *Second International Conference/Workshop on Integrating Geographic Information Systems and Environmental Modeling*. Breckenridge, Colorado: National Center for Geographic Information and Analysis.

As part of the U.S. Geological Survey's Gunnison River Basin Climate Study, hydro-climatic models are used to assess the potential effects of climate change on water resources. Complex hydro-climatic modeling problems commonly involve overlapping data requirements, as well as massive amounts of one- to four-dimensional data in multiple scales and formats. Geographic information systems (GIS) and Scientific Visualization Systems (SVS), combined with advanced statistical capabilities (STAT), are powerful tools for developing and analyzing complex hydro-climatic models. In this paper, a four-component system is presented in which a model, GIS, SVS, and STAT are all accessed from a graphical user interface, providing a tool for spatial-data management and manipulation, model parameterization, visual data interpretation, and model verification.

Hofmann, E.E. (1991). "How do we generalize coastal models to global scale?" in R.F.C. Mantoura, J.M. Martin, and R. Wollast (eds.), *Ocean Margin Processes in Global Change*, John Wiley and Sons, Ltd.

It is now appropriate to begin the development of physical-biological models that treat processes that occur at ocean basin or global scales. Of particular interest is the development of models that can be used to quantify the flux of material from the ocean margins to the open ocean. Hence, it is worthwhile to review the

types of models that could be extended to larger scales and/or used to quantify boundary fluxes and to indicate some of the problems that are associated with extending and using these models. A brief overview of the types of models developed to consider physical-biological interactions in limited coastal regions is presented. This is followed by a discussion of the issues and problems that must be addressed if these regional models are to be extended to larger scales or used to estimate material fluxes across boundaries, such as the shelf-slope boundary. Two issues are of primary concern: mismatches of space and time scales between regional and larger-scale systems, and the degree of complexity that needs to be transferred from regional to larger-scale models.

Jankowski, P., and G. Haddock, Integrated nonpoint source pollution modeling system. Department of Geography, College of Mines and Earth Resources, University of Idaho, Moscow, ID. [Piotr@IDUI1.Bitnet].

The major impediments in using computer models for simulating the consequences of nonpoint source pollution are the intensive data requirements and time involved in compiling the model input file. These problems can be overcome by integrating nonpoint source pollution models with Geographic Information Systems (GIS) pc-ARC/INFO and a dynamic, event-based nonpoint source pollution model. Using the pc-ARC/INFO macro language, Pascal, and batch programming, a menu-driven system was developed that integrates the Agricultural Nonpoint Source pollution model (AGNPS) with pc-ARC/INFO.

Karlson, R.H., and J.B.C. Jackson, (1981). "Competitive networks and community structure: a simulation study," *Ecology*, 62, 670-678.

The results of a series of simulations to determine the effects of competitive networks and hierarchies on species abundance patterns. Restricted to simulations involving spatial competition among sessile, colonial invertebrates in the absence of disturbance. Variables in this model include overgrowth ranking patterns, recruitment rates, growth rates, overgrowth rates, substratum size (i.e., size of a spatial array), and species number.

Kenny, D., and C. Loehle, (1991). "Are food webs randomly connected?" *Ecology,* 72(5), 1794-1799.

A simple random model for food web connectance. We model observed webs as random samples drawn from the universe of all possible randomly connected sets of n objects, with no biological interactions assumed. We then drop out links based on observed link-magnitude data and sampling effects. The resulting

connectance curves bracket the real data, suggesting (1) that food webs may in fact be randomly conneced, and (2) the mere fact that previously proposed models can generate the observed connectance models does not guarantee the correctness of the models. This study also suggests that studies of food web topological properties may bear reexamination.

Krummel, J.R., C.P. Dunn, T.C. Eckert, and A.J. Ayers, A technology to analyze spatiotemporal landscape dynamics: application to Cadiz Township (Wisconsin). Argonne National Laboratory, Environmental Assessment Division, Argonne, IL. [krummelj@smtplink.eid.anl.gov].

As landscape ecology has matured, it has gone beyond description of land-use changes, to examining the functional relationships between spatial patterns of landscapes and ecological processes. Attempts to describe these relationships at larger scales or in complex landscapes have been hampered by the lack of spatially explicit distributed parameter models linked dynamically to geographic information systems (GIS). This paper describes developments we have made to link such models to GIS and to develop visualization methods (a graphical interface) that permits the user to readily manipulate large element files containing model parameters. We then present preliminary results illustrating the effects of pattern (in an agricultural landscape) on water and material flow across a heterogeneous landscape composed of multiple watersheds.

Lakhtakia, M.N., D.A. Miller, R.A. White, and C.B. Smith, GIS as an integrative tool in climate and hydrology modeling. MIT Lincoln Laboratory, Bedford, MA. [email: lakht@psumeteo.psu.edu]

The current generation of climate and hydrology models requires new approaches to the management, analysis and visualization of model inputs and outputs. GIS provides an integrative framework that meets most of these requirements.

Leak, W.B. (1970). "Successional change in northern hardwoods predicted by birth and death simulation," *Ecology*, 51, 794-801.

Two simulation models were used to predict species changes in three deciduous forest cover types in New England. A fixed-rate simulator, employing differences among species in birth/death rates, was used for stands approaching a steady-state condition. A density-related simulator, using birth and death rates related to both species and population size, was applied to stands in dynamic condition. Predicted and actual changes over a 25-year period were reasonably consistent.

Leibowitz, S.G., F.H. Sklar, and R. Costanza, (1989). "Perspectives on Louisiana land loss modeling," in R.R. Sharitz and J.W. Gibbons (eds.), *Freshwater Wetlands and Wildlife*, (pp 729-753). USDOE Office of Scientific and Technical Information.

Louisiana's coastal wetlands are changing rapidly. Although some areas are accumulating new land, the delaic plain of the Mississippi River is losing an estimated 39.4 square miles (102 square km) per year (Gagliano et al., 1981). This paper describes models that have been used to analyze the temporal and spatial patterns of habitat change in coastal Louisiana. Early attempts at understanding wetland loss used areal data for only two points in time. Later, additional time periods were included, giving a better understanding of how these rates change. Next, simple linear models were used to relate land loss to factors sucha s canal density, and multiple regression models were used to examine the interactions associated with wetland loss. Our most current knowledge of wetland loss is based on digitized, high-resolution, aerial photographs from different time periods, along with new forms of spatial statistics. Using distance measures and proximity analysis, these data indicate a decrease in land loss with increased proximity to natural waterways and an increase in land loss with increased proximity to artificial channels. The most complex of the wetland loss models to date is a dynamic simulation model of the coastal marshes of the Atchafalaya River, which attempts to replicate the historical spatial pattern of habitat change and project into the future the implications of various management options.

Levine, S.H., and R.E. Wetzler, (1991). "Pest management through habitat design," in *1991 IEEE International Conference on Systems, Man, and Cybernetics*.

Recent field and modeling results indicate that habitat design can play a significant role in reducing the probability of herbivorous insect infestations of intensively managed ecosystems. In particular, the arrangement of host plants in "patchy" rather than uniform distributions may limit the ability of key pests to find their host plants. We (1) present modeling and simulation results supporting this consclusion, (2) analyze how this reduced level of infestation is achieved, and (3) define patchiness as a property of habitat design that reflects pest search dynamics as well as plant dispersion.

Mackey, B.G., R.A. Sims, K.A. Baldwin, and I.D. Moore, Spatial analysis of boreal forest ecosystems: results from the Rinker Lake case study. Forestry Canada Ontario Region, Sault Ste. Marie, Ontario, Canada.
[email: bmackey@%soo.dnet@cedar.pfc.forestry.ca]

An integrated ecosystem modeling project under way in Northwestern Ontario at Rinker Lake is described. A critical first step is to develop spatially reliable estimates of the landscape processes that control the availability and distribution of energy, moisture and mineral nutrients. These provide a basis for developing spatially-referenced predictive models of plant/vegetation-environment response. The case study is embedded within a parallel regional/province-wide modeling framework. Preliminary results are presented where soil moisture regime is predicted on a 20-m grid over a 900-square km area as a function of the topographic wetness index and the class of geological substrate. Future works aim at refining this model and developing similar spatial models for the mineral nutrient regime. These form the basis for modeling the vegetation component of boreal forest ecosystems at both operational and strategic scales.

May, R.M., and R.M. Anderson, (1979). "Population biology of infectious diseases: part 1," *Nature*, 280, 455-461.

In the first part of this two-part article (see *Nature* 280:361-367), mathematical models of directly transmitted microparasitic infections were developed, taking explicit account of the dynamics of the host population. The discussion is now extended to both microparasites (viruses, bacteria and protozoa) and macroparasites (helminthes and arthropods), transmitted either directly or indirectly via one or more intermediate hosts. Consideration is given to the relation between the ecology and evolution of the transmission process and the overall dynamics, and to the mechanisms that can produce cyclic patterns, or multiple stable states, in the levels of infection in the host population.

Menges, E.S., and O. Loucks, (1984). "Modeling a disease-caused patch disturbance: oak wilt in the midwestern United States," *Ecology*, 65(2), 487-498.

Model predicts tree-by-tree mortality due to oak wilt and describes the level of spread from outside the woodlot, within the lot, as well as transmission from root grafts. This article also describes the time between consecutive deaths and spatial characteristics of patch spreading.

Milne, B.T., K. Johnston, and R.T.T. Forman, (1989). "Scale-dependent proximity of wildlife habitat in a spatially-neutral Bayesian model," *Landscape Ecology*, 2, 101-110.

Organisms may be constrained by the energetic costs incurred while obtaining resources in fragmented landscapes. We used a spatially neutral model of deer wintering habitat to evaluate the effects of landscape fragmentation on the aggregation of deer habitat. The spatially neutral model used Bayesian probabilities to predict where deer wintering areas occurred. The probabilities were conditional on 12 landscape variables measured at 22,750 contiguous 0.4 ha locations. The model predicted deer habitat at each location independently, thereby enabling a comparison of habitat aggregation in observed, simulated, and random distributions of deer habitat. The predictions of the neutral model exhibited greater fragmentation than observed in nature, suggesting that suitable, yet isolated, locations were not visited by deer. The most suitable sites for deer were clumped in the neutral model, regardless of scale. The inclusion of less suitable sites preserved significant aggregation at fine scales but not at broad scales. Species operate at different scales within a landscape, so ecologists, nature reserve designers and natural resource planners may benefit from models that focus on the proximity of habitat sites as a function of both spatial scale and habitat quality.

Mitasova, H., M. Lubos, W.M. Brown, D.P. Gerdes, I. Kosinovsky, and T. Baker, (1995) "Modeling spatially and temporally distributed phenomena: New methods and tools for GRASS GIS," *International Journal of Geographical Information Systems*, Vol 9 (4):433-446.

The concept of GRASS (Geographic Resources Analysis Support System) as an open system has created a favorable environment for integration of process-based modeling in GIS. To support this integration a new generation of tools is being developed in the following areas: (a) interpolation from multidimensional scattered point data, (b) analysis of surfaces and hypersurfaces, (c) modeling of spatial processes and, (d) 3D dynamic visualization. Examples of two applications are given—spatial and temporal modeling of erosion and deposition and multi-variate interpolation and visualization of nitrogen concentration in the Chesapeake Bay.

Mladenoff, D.J., G.E. Host, and J. Boeder, LANDIS: a spatial model of forest landscape disturbance, succession, and management. Natural Resources Research Institute, University of Minnesota, Duluth. [email: dmladeno@ua.d.umn.edu]

LANDIS is a stochastic, spatially explicit model of forest landscape disturbance and succession. It is designed to simulate the forests of the northern Lake States. LANDIS is raster-based and programmed in C++ with both iterative code hierarchical, object oriented data structures. LANDIS simulates succession semi-quantitatively as tree species age classes. This approach allows concentration of model complexity on algorithms that simulate landscape-scale interactions such as seed dispersal on a matrix of land types with differing disturbance regimes. LANDIS contains interacting windthrow and fire disturbance regimes which we believe have not previously been modeled. The model links dynamically with GIS by operating in an ERDAS raster file format and is implemented for both MS-DOS and Unix operating systems. The model includes a graphical interface and its own routines for spatial analysis and calculation of various indices of landscape pattern, and graphical and map output. The model has been developed to analyze changes in landscape pattern with different disturbance regime combinations. This includes forest harvest levels and pattern, as well as natural disturbances. Applications are being developed to examine landscape- and regional-scale management questions such as the effects of landscape change on forest birds, wolf recolonization, and levels of commodity production.

Orland, B. SMARTFOREST: a 3-D interactive forest visualization and analysis system. Imaging Systems Laboratory, University of Illinois at Urbana-Champaign. url=http://imlab9.landarch.uiuc.edu [e-mail: b-orland@uiuc.edu]

Computer visualization is increasingly used to communicate the implications of natural and management changes in biological systems in national parks and forests. Data visualization techniques can be used, not only by scientists but also by managers, the public, and decision-makers, to comprehend massive databases, to interpret dynamic changes, and to evaluate the range of outcomes likely from different management strategies. To date, however, most development has been fragmented, the links between different applications of visualization have been few and poor, and the validity and reliability of visuals representing natural phenomena have not been tested. This paper describes a coordinated program of software development in three areas—data collection, data modeling, and data communication—and describes performance goals for visualization technologies.

Pahl-Wostl, C. (1991). "Patterns in space and time-a new method for their characterization," *Ecological Modeling*, 58, 141-157.

A method, based on information theory and network analysis, was introduced to quantify the functional changes associated with certain spatiotemporal patterns in ecological networks. The potential of the method is illustrated: (a) with a simple model system describing the space and time-dependent growth of phytoplankton species as a function of changes in light availability; and (b) with the evaluation of data for the spatiotemporal pattern of nitrogen uptake by grassland species. It is proposed to aggregate species into functional ataxonomic assemblages according to their functional and spatiotemporal characteristics. This unbiased classification scheme may render data from food webs and network analysis better suited for comparative studies.

Paine, R.T., and S.A. Levin, (1981). "Intertidal landscapes: disturbance and the dynamics of pattern," *Ecological Monographs*, 51, 145-178.

The mussel *Mytilus californianus* is a competitive dominant on wave-swept rocky intertidal shores. Mussel beds may exist as extensive monocultures; more often they are an ever-changing mosaic of many species that inhabit wave-generated patches or gaps. This paper describes observations and experiments designed to measure the critical parameters of a model of patch birth and death, and to use the model to predict the spatial structure of mussel beds.

Perestrello de Vasconcelos, M.J., B.P. Zeigler, and L.A. Graham, (1993). "Modeling multi-scale spatial ecological processes under the discrete event systems paradigm," *Landscape Ecology*, 8(4), 273-286.

Presents a multiscale spatial ecological model of a wet sclerophyllous forest subject to recurrent fires. The model is specified in a Discrete Event Systems framework (DEVS) (Zeigler, 1990) interfaced with a Geographic Information System (GIS), and includes the ability to simulate landscape dynamics at several levels of resolution simultaneously. This is achieved by encoding a modular hierarchical representation of the forest landscape components into a set of nested, interconnected, and spatially referenced dynamic models. The results of the landscape dynamics simulations are displayed as sequences of maps through time, illustrating the potential of this modeling methodology for dealing with complex hierarchical structures that operate at several spatial and temporal resolutions.

Peuquet, D.J. (1984). A conceptual framework and comparison of spatial data models. Cartogaphica, 21(4), 66-113.

Examines the major types of spatial data models currently known and places these models in a comprehensive framework. This framework is used to provide clarification of how varying data models, as well as their inherent advantages and disadvantages, are interrelated. It also provides an insight into how these conflicting demands may be balanced in a more systematic and predictable manner for practical applications, and reveals directions for needed future research.

Raper, J., and Livingstone, D. High level coupling of GIS and environmental process modeling. Department of Geography, Birkbeck College, University of London. [e-mail: RAPER or DAVEL@EARTH.GE.BBK.AC.UK]

Suggests that high level coupling with GIS with environmental modeling can best be achieved using fully integrated approaches. A coastal geomorphological example is described as background to the study. After reviewing the 'compromises' in the spatial representation employed by most 'position-based' GIS, it is suggested that 'object' approaches are likely to offer better solutions. In particular, object approaches allow data modeling at a much higher level than the spatial representations employed and offer tools for the integration of spatial representation and spatial models. Object data modeling and handling of time/behavior are discussed and shown not to be obstacles to an integrated object solution.

Reyes, C., Zamora, F., and Legorreta, G. SIGMA: a geographic information system for atmospheric models of the Mexico City metropolitan area. IBM Scientific Center, Mexico. [Ruben Dario 55, Mexico D. F., MEXICO, 11550].

SIGMA is a GIS coupled with an Atmospheric Modeling System. It has four components: Wind, Emission, Dispersion, and Geographical Subsystems. The first three subsystems have specific functions that allow the user to interact with the corresponding models, input and output files and produce previously designed representations to output either virtual or paper maps.

Rogowski, A. S. Conditional simulation of percolate flux below a rootzone. USDA-ARS-PSWM, University Park, PA. [email: asr2.@psuvm.psu.edu]

A multiple indicator conditional simulation program (ISM3) and a raster based geographic information system (GIS-IDRISI) were used to construct overlays of percolate flux below a rootzone. The approach called for a substitution of conditionally simulated values of hydraulic conductivity (K) into a simplified gravity flow equation to give spatial estimates of flux below a rootzone. These estimates were subsequently used to construct quantity-arrival-time distributions of recharge flux at the watertable.

Scheffer, M. (1990). Multiplicity of stable states in freshwater systems. Hydrobiologia, 200/201, 475-486.

It is shown with the use of minimal models that several ecological relationships in freshwater systems potentially give rise to the existence of alternative equilibria over a certain range of nutrient values. The existence of alternative stable states has some implications for the management of such systems. An important consequence is that signs of eutrophication are only apparent after the occurrence of changes that are very difficult to reverse. Reduction of the nutrient level as a measure to restore such systems gives poor results, but biomanipulation as an additional measure can have significant effects, provided that the nutrient level has been reduced enough to allow the existence of a stable alternative clear water equilibrium.

Seligman, N.a.G. (1992). "Simulation of defoliation effects on primary production of a warm-season, semiarid perennial-species grassland," *Ecological Modeling*, 60, 45-61.

A simulation study conducted on the production potential under grazing of a perennial C4-species grassland. A model of plant growth governed by soil moisture availability and prevailing weather conditions was adapted to account for perenniality, C4 photosynthesis, intra-seasonal regrowth, and defoliation effects. Model behavior was validated against a set of field data obtained from the Nacunan experimental site, Mendoza Province, Argentina. Primary production, defoliation effects, and potential forage use as a consequence of different stocking rates and grazing systems were simulated for two consecutive seasons.

Sham, C.H., Brawley, J.W., and Moritz, M.A. Analyzing septic nitrogen loading to receiving waters: Waquoit Bay, Massachusetts. The Cadmus Group, Inc. [135 Beaver Street, Waltham, MA 02154]

Waquiot Bay, a shallow bay on Cape Cod, Massachusetts, is exhibiting symptoms of eutrophication, largely attributed to septic nitrogen inputs in the drainage basin. This study assessed septic nitrogen inputs by linking the following

components: a three-dimensional groundwater model, a geographic information system (GIS), and a customized loading calculation problem. The groundwater model provided estimates of groundwater movement, delineated as annual "time-bands" across the drainage basin. Using GIS statistical functions and land parcel data, we derived the spatial distribution of residential housing within the various groundwater travel time bands, and generated input for the loading calculation program. Temporal characteristics, such as when building occurred on a parcel, were incorporated in the loading calculation. Since 1940, residential development in the Waquoit Bay drainage area has increased about fifteen-fold. Due to the slow speed of groundwater movement, the bulk of septic nitrogen entering the bay lags behind development by nearly a decade. If residential building could be held at 1990 levels, nitrogen levels input from septic systems will increase by 36 percent over the current levels. At full residential build-out, septic nitrogen loading will increase to more than twice the current levels.

Sklar, F.H., R. Costanza, and J.W. Day, (1985). "Dynamic spatial simulation modeling of coastal wetland habitat succession," *Ecological Modeling*, 29, 261-281.

To adequately model many ecological systems and management problems, spatial dynamics need to be treated explicitly. A dynamic spatial simulation model composed of interacting cells was designed to protect habitat changes as a function of marsh type, hydrology, subsidence, and sediment transport for a generalized coastal wetland area. The model with nine interacting cells was developed to test mathematical formulations and computer algorithms, and to help explain model structure and behavior. Each cell in the model is classified and assigned a habitat parameter 'signature' corresponding to a multidimensional niche space. Large-scale habitat changes ('succession') occur in the model when water and material fluxes between cells produce storages corresponding to the signature of a new habitat. After some time lag to reflect successional changes, the cell parameters are changed to reflect the new habitat signature. In this manner the model can be used to project the impact of natural and man-made changes (i.e., levees, canals) to the system on the spatial distribution and productivity of the various habitats.

Sklar, F.H., K.K. Gopu, T. Maxwell, and R. Costanza, (1993). "Spatially explicit and implicit dynamic simulations of wetland processes," in N.J. Motsh (eds.), *Global Wetlands, Old and New* (pp 719-741), Elseiver Publishing.

Spatial modeling projects of coastal wetlands were aimed at developing tools for improved modeling and analysis of ecological processes at the landscape scale. A spatially implicit serial processing model was used to evaluate the impacts of coastal land-use changes in South Carolina from 1950 to 1987 on plant productivity and nitrogen cycling in tidal freshwater marshes. A spatially explicit parallel processing model was used to evaluate the effects of sea level changes from 1970-1990 on hydrology and salinity in tidal freshwater marshes.

Stoms, D.M., F.W. Davis, and A.D. Hollander, Hierarchical representation of species distributions for biological survey and monitoring, Department of Geography and Computer Systems Laboratory, University of California, Santa Barbara. [email: stoms@geog.ucsb.edu]

Spatial and temporal axes of domain, grain, and sampling intensity can serve as a framework to discuss opportunities for integrating spatial biodiversity data into richer, more complex representations of species distributions. This conceptual framework also highlights many of the problems in integrating data of different spatial, temporal and thematic properties. A recent analysis of the distribution of the orange-throated whiptail lizard in southern California is reviewed as an example of integration datasets. Comparison of representations resulting from different data sources makes biases evident, highlights areas of inadequate sampling, and can lead to new inferences about habitat relationships through convergence of evidence. Improvements in the technology needed to facilitate better integration of distribution models with GIS in the areas of data entry, linkages to tools outside traditional GIS functionality, and new GIS tools to integrate existing datasets are discussed.

Vieux, B.E., N.S. Farajalla, and N. Gaur, Integrated GIS and distributed stormwater runoff modeling. School of Civil Engineering and Environmental Science, University of Oklahoma, Normal. [email: vieux@chief.ecn.uoknor.edu]

Review of recent efforts at integrated modeling of stormwater runoff and the errors propagated in hydrograph response due to attribute errors. Spatially variable infiltration parameters in the Green and Ampt infiltration equation must be captured by a given grid cell resolution. A soil map of the Little Washita watershed in southwest Oklahoma is used to investigate the effects of grid cell resolution and error propagation on distributed modeling of infiltration.

Vieux, B.E., and J. Westervelt, (1992). "Finite element modeling of storm water runoff using GRASS GIS," in B.J. Goodno and and J.R. Wright (eds.), *Computing in Civil Engineering and Geographic Information Systems Symposium*, (pp 712-718). Dallas: American Society of Civil Engineers.

Presents methodologies that are under development combining the finite element method and GRASS GIS. Grass 4.0 is a raster based GIS written by USACERL. GRASS-FEA is an internationally integrated simulation model and GIS software under development that simulates storm runoff and sedimentation. Land managers will be able to use this system to analyze land use changes, and vegetative cover disturbance using inputs from the GRASS database for slope, soils, and vegetative cover.

White, D.A., and M. Hofschen. A spatial model for assessing nutrient loads in rivers and streams. Ohio Environmental Protection Agency and Ohio State University, Columbus. [email: dwhite@central.epa.ohio.gov AND mhofsche@magnus.acs.ohio-state.edu]

Describes a spatial model designed to aggregate pollution sources from upstream drainage areas for land surfaces having point-source and nonpoint-source water pollution effects.

Wu, J. (1994). "A spatial patch dynamic modeling approach to pattern and process in an annual grassland," *Ecological Monographs*, 64(4), 447-464.

Landscapes are hierarchical mosaics of patches that differ in their age, size, shape, content, and other aspects. The Jasper Ridge serpentine grassland exemplifies hierarchical patchiness and pattern-process interactions that are common features of natural ecosystems. Gopher mounds formed each year destroy all the plant individuals underneath and result in a conspicuous spatial pattern in the landscape. A snapshot of the system is, therefore, a reflection of the patch mosaic of gopher mounds that are different in age and species composition and abundance. Based on a patch dynamics perspective, we have developed a spatially explicit patch-based modeling approach to studying landscape pattern and process dynamics. The simulation model (PatchMod) has two major components: a spatially explicit, age- and size-structured patch demographic model and multiple-species planned population dynamics model. We use this simulation model to examine the spatiotemporal dynamics of the disturbance patches and of populations of two species on the local and landscape scales.

Wu, J., J.L. Vankat, and Y. Barlas, (1993). "Effects of patch connectivity and arrangement on animal metapopulation dynamics: a simulation study," *Ecological Modeling*, 65, 221-254.

Results of a simulation model of metapopulation dynamics consisting of two or three habitat patches using STELLA. Simulations show that, given the assumptions of the deterministic model, the metapopulation is doomed to global extinction with or without interpatch immigration when all local populations are below minimum viable population (MVP) size. This suggests that for a cluster of scattered small populations, it is preferable to focus on augmenting individual population sizes rather than enhancing interpatch immigration. In the case when at least one of the subpopulations is above the MVP size, there is a critical size for that subpopulation above which the metapopulation persists and otherwise collapses. Also, when a metapopulation system is composed of more than two patches, the spatial configuration in terms of patch connection and the relative position of the above-MVP subpopulation will have significant effects on metapopulation dynamics and persistence. All simulation results from the three-patch animal metapopulation model suggest that both the number of interpatch connections and the magnitude represented by them are crucial for overall patch connectivity.

Area 12: Environmental Education and Awareness

The complex issues related to understanding and shaping the environmental awareness and resulting behavior of Army military and civilian personnel became known by the mid-1970s. In one early published effort (Goettel, Balbach, and Severinghaus, 1981), the development of a pocket-size training circular was promoted as a means to make troops aware of the environmental "ground rules" of the installation upon which they were training. It was noted that these guidelines were especially hard to transmit effectively to visiting troops, such as those on annual training exercises, who were not "home" at that location throughout the year. Earlier, Fort Irwin Training Circular 1 was prepared as a condition of a special permit to use that location for a major exercise in March 1980. This was prior to its designation as the National Training Center. Similar small (5" x 7" format) training circulars were prepared by USACERL for several installations, and others prepared them in a variety of formats using local resources. Broadly similar field cards, booklets, or pamphlets developed by USACERL or under local authority are in wide use today at many locations.

Through the 1980s, the concept of "awareness" became a regular focus of major command concern. Publication of rules was not adequate to assure environmental compliance, similar to response to many regulations for both public and private institutions. A movement from regulating to one of persuading and educating gradually took form, and the products associated with this persuasion take many forms. Films, slide shows, videotape presentations, posters, T-shirts with slogans, laminated pocket field cards, and many similar tools became part of the awareness "arsenal." Products tailored to scores of locations have been prepared in addition to generalized materials suited to all locations sharing some common characteristics, such as arid soils. In the 1990s, interactive videodisk programs have been developed as an additional tool to train personnel in a variety of environmental responsibilities.

In a more specific directive, General Frederick M. Franks, Commanding General, U.S. Army Training and Doctrine Command (TRADOC), issued guidance in 1991 to all subordinates in which he called for commitment to ethical stewardship, proactive environmental leadership, and personal actions by commanders to protect the environmental resources on Army training lands (TRADOC Environmental Ethic, Memorandum, 21 October 1991). In response, the U.S. Army has developed a master plan for environmental training and doctrinal change for integrating environmental training into existing programs of instruction.

The Office of the U.S. Army Deputy Chief of Staff for Operations and Plans (DCSOPS) User Requirements Survey, conducted in 1994, identifies the need to provide a comprehensive installation-level environmental awareness program as a major requirement, behind only to providing resources and staff. Furthermore, the user requirements in education identify a need for environmental awareness training for both soldiers and civilians. The environmental awareness training for military personnel should be simple, cost-effective and easily updated and should be comprehensive in scope. Training for civilians is needed to increase their awareness of the training mission requirements and the potential environmental impacts. DCSOPS has also identified the need to provide methods to assess the effectiveness of environmental awareness training programs.

Guidance on environmental training seems to be unequivocal and sufficient for incorporating environmental considerations into Army training protocols; meager results up to this point are most likely a result of resistance, bureaucratic barriers, lack of priority, or a synergistic effect of all three. The American public has been consistent in its concern for local environmental issues over the past decade, and the trend for environmentalism is expected to increase into the next decade. As such, the Army has identified strategic, legal, operational, and moral imperatives for environmental protection as it develops its directives for the 21st century (Environmental Considerations in Army Operational Doctrine, White Paper, U.S. Army Engineer School, January, 1995).

The Integrated Training Area Management (ITAM) Environmental Awareness program developed by USACERL is designed to improve troop awareness of environmental issues during field training exercises (FTX). By providing installation-specific guidance about environmental issues, severe environmental damage and its associated costs can be prevented. The Environmental Awareness (EA) curricula is a multimedia approach, incorporating videotapes, computer-based training programs, handbooks, posters, and field cards, with each element designed to provide soldiers with guidance for environmental protection during FTX.

A majority of the products of the environmental awareness and education efforts at USACERL were not formally "published." It is difficult, for example, to publish a set of awareness posters designed to be used in troop unit offices. This has required the use of additional the section 12C, entitled *Products Developed and Distributed.* The listings following Section 12C, then, attempt to group together items of similar nature in some common categories. Some of these items are available for downloading from CERL's home page on the WWW.

12A: Applicable Results

Balbach, H.E., Diana Webb, and R.G. Goettel, *Gallant Eagle 80: Protecting Resources During Training*, Fort Irwin Training Circular 1, March 1980

An 18-page pamphlet in 5" x 7" format containing a set of basic "ground rules" for behavior while conducting a major training exercise. Describes restrictions on use of fire, disturbance of certain wildlife species, waste disposal, and other topics. A foldout map of the installation, showing off-limits areas, is included. 20,000 copies were printed and distributed to each soldier participating in the Gallant Eagle 80 joint training exercise.

Denight, M.L., 1993, *Your Responsibilities to the Red-Cockaded Woodpecker*, Interactive Computer Program presented at the Federal Construction Council Symposium on Continuing Education for Construction Professionals, National Academy of Sciences, Washington, DC, 03 March 1993.

Denight, M.L. and Robyn Simmons. 1993. *USACERL develops aids that help soldiers be more environmentally aware while training*, AEC Environmental Update, 5(1):9.

Goettel, R.G., H. Balbach, and W.D. Severinghaus, *Guidelines for Installations Natural Resource Protection During Training*, USACERL Technical Report N-104, October 1981. ADA107987.

Describes how U.S. Army installation personnel can assemble material for a training package that explains how to protect an installation's natural resources. Suggested text and artwork have been regionalized to allow a reasonable approximation of the specific environments found on most Army installations. Included are explanations of how the appropriate regionalized sections of the package can be selected and reproduced. Instructions are also provided on how an installation specific map and information section can be prepared.

Marlatt, R. M., T. A. Hale, R. G. Sullivan, and R. M. Lacey, *Guidelines for Applying Video Simulation Technology to Training Land Design*, TR EN-93/05, February 1993. ADA264980.

An instructional and reference manual designed to help Army land managers and trainers better apply video simulation technology to their land management activities. This is intended to help land managers communicate technical information in a simple form, easily understood by both technical and nontechnical persons, by visually simulating the effects of land management actions.

Severinghaus, W. D., "Motivation: The Key to Environmental Compliance, 1992, Air and Waste Management, 92-138.09

12B: Underlying Research Information

12C: Products Developed and Distributed

Handbooks

1. Ft. Benning: Training and the Environment, Handbook, 1992
2. Ft. Bragg North Carolina Leader's Environmental Handbook, 1994
3. Ft. Bragg North Carolina Soldier's Environmental Handbook, 1994
4. Ft. Drum Leader's Handbook, 1993
5. Ft. Huachuca Leader's Handbook, 1994
6. Ft. Huachuca Soldier's Handbook, 1994
7. Preserving Ft. Jackson Leader's Handbook, 1992
   Environmental Awareness at Ft. Leonard Wood: Leader's Handbook, 1992
8. Ft. McCoy Leader's Handbook for Terrain Protection, 1993
9. The Joint Readiness Training Center and Ft. Polk Leader's Environmental Handbook, 1993
10. Camp Ripley Minnesota Leader & Soldier Handbook, 1994
11. Ft. Sam Houston and Camp Bullis Leader's Handbook, 1994
12. Ft. Stewart Environmental Handbook Leader's Version, 1994
13. Preserving Yakima Training Center Leader's Handbook, 1992
14. Beale Air Force Base: Natural and Cultural Resources, 1995
15. Davis-Monthan Air Force Base: Natural and Cultural Resources, 1995
16. Langley Air Force Base: Natural and Cultural Resources, 1995
17. Mountain Home Air Force Base: Natural and Cultural Resources, 1995
18. Holloman Air Force Base: Natural and Cultural Resources, 1996

Posters

1. "Don't" (Tank Hitting Tree)
2. "Don't" (Tank in Sagebrush)
3. Always Carry Your Digging Permit
4. Be Part of A Think Tank
5. Be Part of A Think Tank II
6. Be Part Of A Think Tank III
7. Clean Up Your Act! Police Your Bivouac
8. Complete A Police Call in Training Areas
9. Conserve The Land As You Serve Your Country
10. Cover Your Tracks Or They Will Lead to the End of Your Mission
11. Don't Bring Your Training to Ruins
12. Don't Get Caught Dead In Your Tracks..Identify Route of Approach
13. Don't Get Wired!
14. Don't Let Your Training Become A Washout
15. Don't Tread On Me
16. Driving Vehicles Across Dry Lake Beds Is Prohibited
17. Effective Maneuver Drills Prevent POL Spills
18. Eroded Areas Are Environmentally Fragile
19. FIRE! Report All Fires to Range Control
20. FIRE! Report All Fires to Range Control (Photo)
21. Fly High with the American Dream..Protect Endangered Species
22. Food for Thought..Damage to Agricultural Areas is Prohibited
23. Forested Areas Are To Be Used-Not Abused
24. Fort McCoy Environmental Protection: TARP
25. (A) Good Soldier Is Hard to Find (Designated Roads)
26. (A) Good Soldier Is Hard To Find (Camouflage Nets)
27. (A) Good Soldier Is Hard to Find (Concealment)
28. Guard Against Range Fires
29. Handle POL Products With Care
30. Hindsight is 20/20 Stay on Designated Roads
31. If We Don't Stop Soil Erosion, It Will Stop Us
32. If You Can Be Seen, You Can Be Hit
33. Keep It Down..Don't Let Fire Get Out Of Hand
34. Keep the Army on Solid Ground, Use Designated Roads & Trails
35. Keep the National Guard on Solid Ground
36. Keep Vehicles on Established Road Beds, Damage is Costly
37. Know Your Enemy..Maneuver Damage Is a Tactical Error
38. Leave Wetlands & Lush Green Areas Alone
39. Not All Mountains Are Just Mountains..Historical Areas

40. Pine Plantations Are To Be Used Not Abused
41. Police Training Areas Before & After Use
42. Preserve the American Spirit
43. Preserve the Spirit of America
44. Prevention is the KEY
45. Protect Endangered Species, It's The Law
46. Protect Fort McCoy's Wetlands
47. Protect the Balance Between Environment and Training (Sagebrush)
48. Protect the Balance Between Environment and Training
49. Protect The Balance Between Environment and Training (RCW)
50. Protect The Soil..Environmental Damage is a Tactical Error
51. Put Litter In Its Place
52. Put On Your Thinking Caps
53. Range Fires Destroy Training Land..Report All Range Fires
54. Set That Net: Learn the Craft of Camouflage
55. Some Sage Advice From The Major...Avoid Maneuver Damage
56. SOS: Save Our Soils
57. Startled Animals Can Reveal Your Tactical Position
58. Stay On Designated Tank Roads...Or Your Name Will Be Mud
59. Stay On Target: Our Aim Is Protection of Training Areas
60. Steer Clear of Range Animals
61. Stop Destruction of Plants: Avoid Neutral Steer Turns
62. Survival is....NO ACCIDENT
63. Tree Nurseries Are Restricted Areas: KEEP OUT
64. Tree Plantations Are Restricted Areas: KEEP OUT
65. Wetlands Are Protected Areas (Photos)
66. Where the Deer & the Antelope Play??
67. Why Don't You Just Drink It Straight Out Of The Can?
68. Wildlife Food Plots Are Restricted Areas: KEEP OUT

Field Cards

1. Ft. Benning Leader's Guide, 1992
2. Ft. Benning Soldier's Field Guide, 1992
3. Camp Blanding Training Site Leader's Guide, 1992
4. Camp Blanding Training Site Soldier's Field Guide, 1992
5. Ft. Bragg, NC, Environmental Guide, 1994
6. Ft. Drum, NY, Environment and Mission Leader's Guide, 1993
7. Ft. Drum, NY, Environment and Mission Soldier's Pocket Guide, 1993
8. Ft. Huachuca Hazardous Waste Card, 1994
9. Ft. Huachuca Leader's Card, 1994

10. Ft. Huachuca Soldier's Card, 1994
11. Ft. Jackson, SC, Environment and Mission Leader's Guide, 1993
12. Ft. Jackson, SC, Environment and Mission Soldier's Pocket Guide, 1993
13. Ft. Knox Leader's Guide, 1993
14. Ft. Knox Soldier's Guide, 1993
15. Leesburg Training Site, SC, Leader's Guide, 1993
16. Leesburg Training Site, SC, Soldier's Guide, 1993
17. Ft. Leonard Wood, MO, Field Card for Commanders and Leaders, 1992
18. Ft. McCoy Terrain Protection Leader's Field Card, 1993
19. Ft. McCoy Terrain Protection Soldier's Field Card, 1993
20. Joint Readiness Training Center at Ft. Polk Soldier's, Environmental Compliance Field Card, 1993
21. Ft. Sam Houston and Camp Bullis Environmental Field Guide, 1994
22. Ft. Stewart Leader's Card, 1994
23. Ft. Stewart Soldier's Card, 1994
24. Yakima Training Center Leader's Field Card, 1992
25. Yakima Training Center Soldier's Field Card, 1992
26. Yakima Training Center Vehicle Logbook Card, 1992

Videotapes

1. Camp Ripley: Training and the Environment, 1994
2. Camp Shelby: Training and the Environment, 1994
3. Environmental Awareness, 1994
4. Ft. Benning: Training and the Environment, 1993
5. Ft. Bliss: Training and the Environment, 1993
6. Ft. Bragg: Training and the Environment, 1993
7. Ft. Chaffee: Training and the Environment, 1993
8. Ft. Dix: Training and the Environment, 1994
9. Ft. Drum: Training and the Environment, 1993
10. Ft. Huachuca: Training and the Environment, 1994
11. Ft. Jackson: Training and the Environment, 1993
12. Ft. Knox: Training and the Environment, 1993
13. Ft. Leonard Wood: Training and the Environment, 1993
14. Ft. McCoy: Training with the Environment (Leader's), 1993
15. Ft. McCoy: Training with the Environment (Soldier's), 1993
16. Ft. Polk's Archeological Resources, 1994
17. Ft. Polk: Training and the Environment, 1994
18. Ft. Riley Legacy, Cultural Resources, 1994
19. Ft. Riley Legacy, Natural Resources, 1994
20. Ft. Riley: Training and the Environment, 1993

21. Ft. Sam Houston & Camp Bullis: Training & the Environment, 1994
22. Ft. Stewart: Training and the Environment, 1994
23. The Guard's Most Wanted, MNARNG Hazardous Waste Mgmt, 1994
24. Leesburg Training Center:Training & the Environment, 1993
25. LRAM Overview, 1994
26. NCARNG: Training and the Environment, 1994
27. 7th ATC, Germany: Training and the Environment, 1993
28. Yakima Training Center: Training and the Environment, 1992
29. Ft. Drum: Natural Resources Intern Program, 1995
30. Ft. Drum: Cultural Resources Intern Program, 1995
31. Ft. Drum: HAZMAT Copy, 1995
32. MNARNG: Ten and a Half Steps to Facility Compliance, 1996

Area 13: Land Contamination

The land on military installations may become contaminated in many ways. One is through its use as an impact area for dud-producing explosives, such as artillery shells. Another is through its having been used for authorized or unauthorized disposal of some form of hazardous waste. The focus at USACERL is not on either of these areas, where the problem is considered to require "cleanup" or "environmental restoration." Most efforts have been related to "minor" contamination as a side effect of training or field maintenance activities, especially that which may have ecological consequences. The residues from smoke pots and smoke grenades have been examined, as has the residue from explosives and their breakdown products.

13A: Applicable Results

Dierenfeld, E.S., and E.W. Novak, *Quantification of hexachloroethane munitions and associated environmental chemical loads*. USACERL Technical Report N-87/17, Jun 1987. ADB114815L.

Documents the extent to which hexachloroethane (HC) smoke munitions are used on Army installations, calculates the environmental chemical loads resulting from this use, and assesses the munitions' potential hazardous effects to native flora and fauna. Three types of munitions were examined: smoke projectiles, smoke grenades, and smoke pots. Their use by various Major Commands was quantified for FY81 through FY84.

Kerster, H.W., D.J. Schaeffer, and K.A. Reinbold, 1988, *Assessing Ecosystem Impacts from Simulant and Decontaminant Use*, CRDEC Technical Report CR-88059/ USACERL Technical Report N-88/15, July 1988. ADA196846.

Chemicals for simulation and decomposition of chemical warfare agents may alter the ecosystems of training sites and their environs. This report presents methods and proposes a newly devised approach to rank those chemicals for damage potential. Further data necessary to reduce ranking errors are identified, and chemical and ecological monitoring of training sites and their surroundings are recommended.

Messenger, Manette, et al., *Tracking Hazardous Materials through Army Installations*, USACERL TR N-149, 1983. ADA129103.

Investigates the feasibility of tracking hazardous material through procurement, distribution, use, collection, and disposal of U.S. Army fixed facilities. This is to comply with government regulations of hazardous waste under the Resource Conservation and Recovery Act.

Messenger, Manette, R. Nichols and R.D. Webster, *Description and Implementation of the Hazardous Materials Tracking System (TRACKER)*, USACERL TR N-180, 1984. ADA144107.

Outlines the features of a computerized tracking system that interfaces the Army installation procurement system with a database of known hazardous items to produce a monthly listing of the types and amounts of hazardous materials procured by each unit on post. This can be used to comply with current laws and Army Regulations 200-1 and 420-47.

Messenger, Manette, *Protecting the Environment During Maintenance Activities*, 17 pages, soldiers' handbook, July 1992.

Novak, Edward W, Lester Lave, James Stukel, and David J. Schaeffer, *A Revised Health Risk Assessment for the Use of Hexachloroethane Smoke on an Army Training Area*, USACERL Technical Report N-87/26, September 1987, 56 pp. ADA187238.

Hexachloroethane (HC) smoke has been used in military training for 50 years. Tests have consistently shown that many of the compounds produced when the material is burned are known or suspected carcinogens. This report recommends that, at a minimum, the Army enforce existing regulations requiring that personnel use protective masks during smoke exercises. The non-human environmental risks are unquantified.

Scholze, R.J. and M.P. Mcneilly, *Summary of Best Management Practices for Nonpoint Source Pollution*, USACERL Technical Report EP-93/06, Aug 1993. ADA276875.

Presents a range of alternatives, both structural and nonstructural, that may be used to ensure that Army major commands and installations are able to comply with legislative and regulatory requirements that control nonpoint source (NPS) pollution.

13B: Underlying Research Information

Balbach, H.E., P. Houghland, and M.K. Chawla, *Final Environmental Assessment for Global Commons Movement of Chemical Munitions from the Solomon Islands*, U.S. Army Engineer Division, Pacific Ocean, Honolulu, HI, April 1991; 205pp.

Banwart, W., D. Chen, H.E. Balbach, and E. Novak, "Plant Uptake of RDX from Spiked Soils," *Agronomy Abstracts, 1991 Annual Meetings of the American Society of Agronomy*, October 1991, p 35.

Reports on the quantities and concentrations of RDX (up to 400 ppm) that were taken up by several plant species when grown in soils and nutrient solutions containing the material.

Banwart, W.L., J. Chang, H.E. Balbach, and E. Novak, "Plant Uptake of RDX," *Agronomy Abstracts, 1990 Annual Meetings of the American Society of Agronomy*, October 1990, p 8.

Several plant species were shown to take up measurable levels of RDX when grown in nutrient solutions containing the material.

Banwart, W.L., J.J. Hassett, T.C. Granato, and H.E. Balbach, "Soils Analysis of Ridge and Furrow Explosives Disposal Area at Joliet Army Ammunition Plant," *1988 Annual Meetings of the American Society of Agronomy*, November 1988, p 8.

Davenport, R., L. Johnson, D. Schaeffer, and H.E. Balbach, "Phototoxicology 1: Light-Enhanced Toxicity of TNT and some Related Compounds to Daphnia magna and Lytechinus variagatus Embryos," *Ecotoxicology and Environmental Safety* 27:14-22, 1994.

Getz, L.L., A.W. Haney, R.W. Larimore, J.W. McNurney, H.V. Leland, P.W. Price, G.L. Rolfe, R.L. Wortman, J.L. Hudson, R.L. Solomon, and K.A. Reinbold, "Transport and distribution in a watershed ecosystem," in W.R. Boggess (ed.) *Lead in the Environment.* National Science Foundation report NSF/RA-770214. U.S. Government Printing Office, Washington, DC, 1977.

Johnson, L., R. Davenport, H. Balbach and D. Schaeffer, "Phototoxicology 2: Near Ultraviolet Light Enhancement of Microtox® Assays of Trinitrotoluene and Aminodinitrotoluenes," *Ecotoxicology and Environmental Safety*, 27:23-33, 1994.

Johnson, L., R. Davenport, H. Balbach and D. Schaeffer, "Phototoxicology 3: Comparative Toxicity of Trinitrotoluene and Aminodinitrotoluenes to Daphnia magna, Dugesia dorotocephala, and Sheep Erythrocytes," *Ecotoxicology and Environmental Safety*, 27:34-49, 1994.

Johnson, L., R. Davenport, D. Schaeffer, and H.E. Balbach, "Light Enhanced Toxicity of 2,4,6-Trinitrotoluene (TNT) and Related Compounds," *Agronomy Abstracts, 1992 Annual Meetings of the American Society of Agronomy*, November 1992, p 10.

Reinbold, K.A., and G.L. Rolfe, "Lead concentrations in an ecosystem including rural and urban areas," *Illinois Research* 18:12-13, 1976.

Reinbold, K.A., J.J. Hassett, J.C. Means, and W.L. Banwart, "Adsorption of Energy-related Organic Pollutants: A Literature Review." Ecological Research Series No. EPA-600/3-79-086. U.S. Environmental Protection Agency, Athens, Georgia. 170 pp, 1979.

Reinbold, K.A., R.S. Wentsel, E.E. Herricks, H.W. Kerster, and D.J. Schaeffer, "Environmental hazard ranking of chemical agent simulants." Proceedings of the *1986 U.S. Army Chemical Research, Development and Engineering Center Scientific Conference on Chemical Defense Research*, pp1057-1062, 1987.

Rolfe, G.L., K.A. Reinbold, and A. Haney, *Environmental Contamination by Lead and Other Heavy Metals*. Final Report to National Science Foundation RANN Program. Five volumes, 1977. *Vol I. Introduction and Summary*, G.L. Rolfe and K.A. Reinbold; *Vol II. Ecosystem Analysis*, G.L. Rolfe, A. Haney, and K.A. Reinbold; Vol III-V, G.L. Rolfe and K.A. Reinbold, eds., *Vol III. Distribution and Characterization of Urban Dusts*, R.L. Solomon and D.F.S. Natusch; *Vol IV. Soil - Water - Air - Plant Studies*, compiled by D.E. Koeppe; *Vol V. Synthesis and Modeling*, by G.L. Wheeler, G. Provenzano, and R. Resek.

Schaeffer, D.J., W.R. Lower, S. Kapilla, A.F. Yanders, R. Wang, *Preliminary Study of Effects of Military Obscurant Smokes on Flora and Fauna During Field and Laboratory Exposures*. USACERL Technical Report N-86/22, December 1986. ADA176328.

Report of a study conducted to determine whether tests could be developed to demonstrate measurable changes in organisms exposed to smokes and to evaluate whether short exposure to smokes produced measurable changes in the organisms tested. Fog oil, hexachloroethane, and tank diesel smokes were tested in the field and chemically analyzed at distances from the source ranging from 15 to 150m. The tests developed were deemed adequate for indicating changes in the species caused by the smokes.

Schaeffer, D.S., H.W. Kerster, E.E. Herricks, K.A. Reinbold, E.W. Novak, and R.S. Wentsel, "Assessing ecosystem impacts from simulant and decontaminant use." *J. Hazardous Materials* 18:1-16, 1988.

Wheeler, G.L., G.L. Rolfe, and K.A. Reinbold, "A simulation model for lead movement in a watershed," *Ecological Modeling* 5:67-76, 1978.

Area 14: Management of Fugitive Dust

Since 1946, the U.S. Army Corps of Engineers has conducted a comprehensive research program on pavement maintenance, soil stabilization, and trafficability. Associated studies investigated the development and evaluation of dust control materials for unpaved surfaces. Primary consideration was given to materials that could be blended with soils to a relatively shallow depth to provide a solid, dust free, waterproof soil surface in support of military operations over soft ground.

From 1966 to 1974, the U.S. Army Engineer Waterways Experiment Station (CEWES) pursued a program to identify suitable dust control materials for use in the Southeast Asia theater of operation. During this period, pavement engineers at CEWES conducted intensive research, field experimentation, and evaluations of 315 potential dust control materials. In conjunction with these dust control material evaluations, additional work investigating the development of efficient dustproofing techniques and procedures was also undertaken. Much of this work was directed toward identifying promising dust palliatives, developing procedures and techniques for applying these agents in the interest of tactical considerations, and reducing maintenance requirements for military vehicles operating under dusty conditions.

Numerous promising materials and techniques were developed from the aforementioned efforts and during the mid-1980s, results of several relatively small scale Facilities Technology Application Test (FTAT) demonstrations were conducted by CEWES. The resulting publications addressed procedures and techniques for dustproofing unsurfaced roads and other areas on military installations using common, industry standard suppressants such as brine solutions, polyvinyl acetate/acrylic emulsions, and various hydrocarbon, asphalt, and tar oil emulsions. The primary focus was still on roads and trails.

During the early 1980s, the U.S. Army Construction Engineering Research Laboratories (USACERL) began investigating fugitive dust and dust control in relation to National Air Quality Standard compliance issues. The primary objective of this work involved developing designs and monitoring criteria for using high volume air sampling systems to collect total suspended and respirable particulate air quality data associated with various dust control techniques and training activities at Fort Carson, Colorado. Consideration was given to dust resulting from training exercises conducted across wide areas in addition to travel on unpaved roads and trails. Dust control techniques investigated included industry standard chemical suppressants (magnesium chloride brine solutions and asphalt, oil, and lignin based emulsions) as well as fabric barriers.

In 1995, researchers at USACERL and CEWES began collaborative efforts focusing on training land dust control with troop safety as a primary objective. Much of the previous field testing research and accompanying results were based on unreplicated studies using qualitative dust control data that may not be representative of conditions encountered under normal training activities. Therefore, replicated, large scale evaluations of environmentally safe, persistent materials capable of controlling dust obscurance on intensively used sites are planned. Levels of dust obscurance associated with different materials will be quantified using video imaging technologies. Although development of this technology has not been attempted before, it has important safety implications for determining the degree of dust obscurance encountered during training exercises. Once developed, this technology may have potential benefits for other allied fields of study such as wind erosion dynamics.

14A: Applicable Results

Armstrong, Jeffrey P., "Dustproofing Unsurfaced Areas: Facilities Technology Application Test Demonstration, FY 86," U.S. Army Engineer Waterways Experiment U.S. Army Engineer Waterways Experiment Station (CEWES), Miscellaneous Paper GL-87-19, Aug 1987. ADA185185.

Provides results, recommendations, procedures, and costs associated with using calcium and magnesium chloride brine solutions to control dust on crushed limestone roads and sandy clay assault airstrips.

Departments of the Army and the Air Force., "Dust Control for Roads, Airfields, and Adjacent Areas," Technical Manual TM 5-830-3, Washington, DC, 1987.

Grau, Richard H., *Evaluation of Methods for Controlling Dust*, CEWES Technical Report GL-93-25, Sep 1993. ADA270527.

Describes laboratory methodology to evaluate and select commercially produced dust control materials for further field testing. Provides results of field testing on seven products deemed suitable for use on helipads and wheeled and tracked vehicle roadways.

Hass, Robert A., *Dustproofing Unsurfaced Areas; Facilities Technology Application Test Demonstration, FY 85*, CEWES Technical Report GL-86-20, Dec 1986. ADA176861.

Provides results, recommendations, procedures, and costs associated with using magnesium chloride brine solutions to control dust on silty sand tank trails and sandy clay assault airstrips.

Houston, T.D., Jr., "In Place Performance Test, Evaluation Studies, Investigation of Magnesium Chloride for Dust Control," Directorate of Engineering and Housing, Fort Stewart, Technical Report V2 00092-2-J, Jul 1983.

Leese, G.W., *Helicopter Downwash Blast Effects Study*, CEWES Technical Report 3-664, 1964. AD452177.

Leese, G.W., "UH-1H Downwash Velocity Measurements," CEWES Miscellaneous Paper S-72-31, 1972. ADA034667.

Leese, G.W., and J.T. Knight, "Helicopter Downwash Data," CEWES Miscellaneous Paper S-74-17, 1974. AD780754.

Oldham, Jessie C., Royce C. Eaves, and Dewey W. White, Jr., "Materials Evaluated as Potential Soil Stabilizers," CEWES Miscellaneous Paper S-77-15, Sep 1977. ADA045470.

Provides documentation and additional reference information for over 300 materials tested and evaluated as potential soil stabilization agents by the U.S. Army Corps of Engineers during the period between 1946 and 1975. Material categories include acids, asphalt, cement, lime, resins, salts, and silicates.

Schanche, G.W., and Martin J. Savoie, *Fort Carson Fugitive Dust Generation and Transport Study: Lessons Learned*, USACERL Technical Report N-117, Nov 1981. ADA110330.

Study performed to determine if fugitive dust generated by Fort Carson training activities was adversely affecting the Air Quality Control Region. Data were collected from 1977 to 1979. The conclusion was that average ambient levels at Fort Carson were not significantly different from regional background, but that on Fort Carson, significant obscuration was associated with heavily traveled roads and assembly areas. Control measures are recommended.

Styron, C.R., and R.C. Eaves, "Investigation of Dust Control Materials," CEWES Miscellaneous Paper S-73-70, 1973. AD774834.

Styron, Clarence R., and Alston C. Spivey, Jr., *MX Road Design Criteria Studies, Report 2, Investigation of a Proprietary Material for Dust Control*, CEWES Technical Report GL-82-11, Sep 1982. ADB069056.

Provides results and recommendations from laboratory and field testing for using magnesium chloride and polyvinyl acetate solutions to control dust on lightly used gravel roads. Data concerning weathering and skid resistance are also included.

Styron, Clarence R., Robert A. Hass, and Karen Kelley, *Dustproofing Unsurfaced Areas; Facilities Technology Application Test Demonstrations, FY 84*, CEWES Technical Report GL-85-11, Sep 1985. ADB094557.

Provides results, recommendations, procedures, and costs associated with using magnesium chloride and polyvinyl acetate solutions to control dust on silty sand and clayey sand tank trails and warehouse loading/unloading sites.

14B: Underlying Research Information

Leese, G.W., "UH-1H Downwash Velocity Measurements," CEWES Miscellaneous Paper S-72-31, 1972. ADA034667.

Leese, G.W., and J.T. Knight, "Helicopter Downwash Data", CEWES Miscellaneous Paper S-74-17, 1974. AD780754.

Oldham, Jessie C., Royce C. Eaves, and Dewey W. White, Jr., "Materials Evaluated as Potential Soil Stabilizers," CEWES Miscellaneous Paper S-77-15, Sep 1977. ADA045470.

Provides documentation and additional reference information for over 300 materials tested and evaluated as potential soil stabilization agents by the U.S. Army Corps of Engineers during the period between 1946 and 1975. Material categories include acids, asphalt, cement, lime, resins, salts, and silicates.

DISTRIBUTION

Chief of Engineers
ATTN: CERD-L

Defense Technical Information Center 22060-6218
ATTN: DTIC-O (2)